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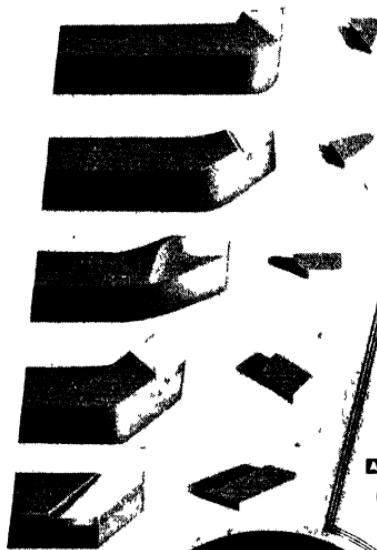
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# DICTIONARY OF METALS AND ALLOYS

THEIR COMPOSITION AND CHARACTERISTICS

With Special Sections on Plating, Polishing,  
Heat Treatment, Metal Spraying, Rust-  
proofing, Chemical Colouring,  
and Useful Tables

EDITED BY

F. J. CAMM

EDITOR OF "PRACTICAL ENGINEERING"

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## INTRODUCTION

METALS are still, in many respects, a mystery to us, and much of the information which we have garnered about them is still of the rule-of-thumb kind.

The reader who uses this present dictionary, however, can rely upon having at hand a mass of modern information on the subject of metals and their alloys. Whilst the dictionary is not intended as a compilation for the metallurgist, the information which it contains will be found of great use to practical engineers.

Many treatises and handbooks on descriptive metallurgy are available, but not one of them is arranged in such a manner as to give information with the least possible amount of trouble.

This dictionary, therefore, aims at meeting this need. Its object is to enable the busy and mechanically-minded reader to put his finger *at once* on the information he requires. Information which, for the purpose in view, is useless has been rigorously excluded from this dictionary in order to keep it within reasonable bounds. Yet every known metal is included in the dictionary and almost every type of commercial metallic alloy.

Many very highly specialised alloys bear no specific name, these being simply represented by a series of code letters, as, for example, "P.66/7 alloy." Such alloys have been omitted from this present compilation, but in all cases the general type of alloy to which they belong has been included. Thus, mention is made of the famous "R.R." alloys, yet their various "Code-number" alloys have necessarily had to be excluded in view of their great numbers.

Sometimes, also, the reader may note that the percentages of the constituents of an alloy do not add up to 100. In all such cases, the difference must be ascribed to the presence of impurities which usually accompany the alloying ingredients and which are not readily got rid of.

The dictionary is adequately cross-referenced. It is, in fact, a handy and straightforward compilation of salient and useful facts regarding all the known metals and nearly all the known commercial alloys, and, as such, it is presented to the reader in the hope that it will long remain a quick-reference compilation of practical use, instruction and interest.

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# DICTIONARY OF METALS AND ALLOYS

## LIST OF ABBREVIATIONS

The following abbreviations are used throughout this Dictionary

At. No.	.	.	.	.	.	.	Atomic Number
At. Wt.	.	.	.	.	.	.	Atomic Weight
M.P.	.	.	.	.	.	.	Melting Point
B.P.	.	.	.	.	.	.	Boiling Point
Sp. Grav.	.	.	.	.	.	.	Specific Gravity
Sp. Ht.	.	.	.	.	.	.	Specific Heat
Coef. Exp.	.	.	.	.	.	.	Coefficient of Expansion
Therm. Cond.	.	.	.	.	.	.	Thermal conductivity
Elec. Cond.	.	.	.	.	.	.	Electrical conductivity

Table of Chemical Symbols are given on page 131.

## A

**Abyssinian Gold.**—(See **Talmi Gold.**)

**Acid Bronze.**—An acid-resisting alloy, sometimes used for mine pumps. Composition : nickel, 1.50% ; lead, 17% ; copper, 73.5% ; tin, 8%.

**Actinium.**—A radio-active metallic element. Chemical symbol, Ac ; At. No. 89 ; At. Wt. 227. Discovered by Debierne in 1899 in uranium residues. Little is known about it but it is apparently intermediate in properties between calcium and lanthanum.

**Admiralty Gunmetal.**—A bronze having the composition : copper, 88% ; tin, 10% ; zinc, 2%. Has a tensile strength of 19 tons per square inch.

**Aeral.**—An aluminium alloy of the composition : copper, 3.5% ; magnesium, 1.8% ; silicon, 0.6% ; cadmium, 2.25%—remainder aluminium. Tensile strength approximately 30 tons per square inch.

**Aerolite.**—A light aluminium alloy of complex proportions. Composition : aluminium, 91.93% ; zinc, 0.12% ; silicon, 0.45% ; iron, 0.97% ; copper, 1.15% ; magnesium, 0.38% ; Sp. Grav., 2.74.

**Aeron.**—A modern aluminium alloy containing 4% of copper and 1% of silicon. Is hard and strong. Can be heat-treated, in which state it will develop a tensile strength of 25 tons per square inch.

**Afénide.**—French jewellery metal composed of nickel or German silver.

## AGE HARDENING

**Age Hardening.**—The property which certain alloys possess of automatically hardening themselves when left for a few days at ordinary temperatures after having been quenched in water. Changes in the grain structure of such alloys underlie this phenomenon.

Aluminium-magnesium alloys and aluminium-copper-silicon alloys are particularly susceptible to age hardening.

**Ageing.**—Metallurgical term referring to the improvement in characteristics which some alloys undergo, particularly those of aluminium, after they have been kept for some time.

**Aich's Metal.**—Average composition: copper, 60.66% ; zinc, 36.58% ; tin, 1.02% ; iron, 1.74%. It is hard and tough, and, being resistant to sea-water, has been used as a sheathing metal for ships' bottoms. It has a golden colour.

**Air-hardened (or Air Hardening) Steels.**—These are alloy steels which have been (or may be) hardened by air-cooling under controlled conditions.

**Ajax Metal.**—An anti-friction bearing metal. Composition: copper, 80.24 parts ; tin, 10.98 parts ; lead, 7.27 parts ; arsenic (or phosphorus), 0.37 parts. The arsenic or phosphorus acts as a hardening agent.

**Albata Metal.**—Composition : copper, 40 parts ; zinc, 32 parts ; nickel, 8 parts.

**Alclad.**—A metal consisting of duralumin with a coating of pure aluminium rolled on. It has good corrosion resistance.

**Alcumite.** A non-ferrous alloy resembling gold ; melting point, 1900° F. approx. An aluminium bronze alloy with copper-base, and some iron, manganese and nickel. It can be cast, welded and forged. Sp. Grav. 8.3 ; weight, 0.299 lb. per cubic inch. Brinell hardness 130-190 ; malleable ; cutting speed, 80 ft. per minute.

**Aldal.**—An aluminium alloy of the following approximate composition : copper, 4.0% ; magnesium, 0.5% ; manganese, 0.5% ; silicon, 0.6%—remainder aluminium. Is hard and possesses a tensile strength of between 25 and 35 tons per square inch.

**Aldebaranium.**—Obsolete name for Ytterbium, proposed by Auer von Welsbach in 1906.

**Aldrey.**—A modern aluminium-magnesium-silicon alloy. Composition : magnesium, 0.5% ; silicon, 0.6%—remainder aluminium. In this alloy, the magnesium and silicon act as hardeners. The alloy can be heat-treated. Tensile strength, 20-22 tons per square inch.

**Aldural.**—A corrosion-resisting brand of duralumin (Vickers patent) ; it consists of sheet or strip duralumin plated on both sides with a coating of high purity aluminium, to a thickness of 5% on each side. (See **Duralumin**.)

**Alfenide Metal.**—Composition : copper, 60 parts ; zinc, 30 parts ; nickel, 10 parts ; plus traces of iron. Similar to Albata metal. Is resistant to dilute acids.

**Alferium.**—A French aluminium alloy used in aero construction. Composition : copper, 2.5% ; magnesium, 0.6% ; manganese, 0.5% ; silicon, 0.3%—remainder aluminium. Tensile strength about 30 tons per square inch.

**Alger Metal.**—A tin-antimony alloy. Composition : tin, 90% ; antimony, 10%.

**Algiers Metal.**—A tin-antimony alloy, little used nowadays. Composition : tin, 90% ; antimony, 10%. Sometimes contains copper also. It is white and takes a good polish.

**Alkali Metals.**—This well-known family of metallic elements comprises the following members : lithium, sodium, potassium, rubidium, caesium. The name was so given on account of the strongly alkaline nature of the compounds (particularly the hydroxides) of these metals, as, for example, caustic soda (sodium hydroxide).

**Alkaline Earth Metals.**—These are the metals, calcium, strontium and barium—so-called because they are derived from “earths” (such as lime) which are alkaline in nature.

**Allan's Metal.**—A copper-lead alloy (or so-called “tin-free” bronze). Composition : copper, 55% ; lead, 45%. Used for Diesel engine piston rings.

**Allautal.**—This consists of the aluminium alloy, “Lautal,” having a coat of pure aluminium rolled on to it. It is corrosion-resistant.

**Alloy.**—A mixture and/or combination of two or more metals forming an apparently homogeneous mass. Alloys can be produced by the simple admixture of the molten metals, by the smelting of mixed ores, by electrolytic methods or by the compression of mixed metallic powders. Alloys containing mercury are called *amalgams*.

When metals are alloyed together they (a) dissolve in each other in any proportions but without actual chemical combination ; or (b) chemically combine with one another, such resulting compounds in some cases dissolving in the excess of pure metal present ; or (c) dissolve in one another to a limited extent ; or (d) remain undissolved in one another, in which latter case they will tend to separate out in layers when the metal cools.

The general effect of alloying metals together is to lower the melting point and conductivity, increase the hardness, and sometimes the strength of the metal. Colour changes often are brought about by alloying, and in many other ways, the properties of the alloying metals are profoundly modified in the resultant alloys.

## ALLOY STEELS

(The word "alloy" is considered to be derived from the Latin *alligo*, to bind together.)

**Alloy Steels.**—These are varieties of steel containing considerable percentages of other metals, such as tungsten, chromium, nickel, manganese, etc., which have been added for the sake of increasing the hardness, strength or corrosion-resistance of the metal, or for some other special purpose. Such steels are also known as "Special Steels." They are detailed under their individual names.

**Alluvial Gold.** Gold obtained from sands, gravels and grits occurring on the beds of ancient streams. The gold in such localities usually takes the form of small scales or rounded grains, and is known to the miners as "gold dust."

**Almag.**—An aluminium alloy. Composition: copper, 2.5%; magnesium, 0.7%; silicon, 0.6%—remainder aluminium. Tensile strength about 25 tons per square inch. Is very hard and enduring.

**Almasilium.**—A modern aluminium alloy of French origin. Contains: magnesium, 1.0%; silicon, 2.0%—remainder aluminium. Can be heated-treated, and has considerable hardness. Tensile strength about 22 tons per square inch.

**Almelec.**—A recent aluminium alloy containing magnesium (0.7%) and silicon (0.5%) as hardening agents. Tensile strength about 20 tons per square inch.

**Alnico.**—An aluminium-nickel-cobalt steel used for making permanent magnets and magnet cores. It offers a maximum amount of magnetic energy per unit mass of metal and, in this respect, constitutes a great advance on the old magnet steels. Composition: steel, 50%; aluminium, 20%; nickel, 20%; cobalt, 10%.

**Alpax.**—An aluminium-silicon alloy, originally invented by Aladar Pacz, after whom it is named. It contains 87% of aluminium and 13% of silicon. It is ductile and fine-grained, and has a silvery-white colour.

**Alpha Iron.**—Below 768° C. iron is known as Alpha Iron. (See **Beta, Gamma and Delta.**)

**Aludur.**—A modern aluminium alloy containing 0.6% of magnesium and 0.88% of silicon. It is heat-treatable and has a tensile strength of 20 tons per square inch.

**Alumel.**—A nickel alloy used in electrical thermometers and thermo-junctions. Composition: nickel, 94%; aluminium, 2%; silicon, 1%; manganese, 2.5%.

**Aluminac.**—An alloy similar to **Alpax** (which see).

**Aluminised Yellow Brass.**—A variety of brass containing up to 1% of aluminium. When aluminium is added in small quantity to a brass, the zinc content of the latter can be higher than when the aluminium is not added, thus making for a light-

coloured brass. The following is an aluminised yellow brass made for saddlery and harness purposes : copper, 55.25 parts ; zinc, 41.25 parts ; lead, 3 parts ; aluminium, 0.5 parts.

**Aluminium.**—Metallic element. Chemical symbol, Al ; At. No. 13 ; At. Wt. 27 ; M.P. 658° C. ; B.P. 1,800° C. ; Sp. Grav. 2.58 ; Sp. Ht. 0.2253 ; Coef. Exp. 0.00002313 ; Therm. Cond. (Silver = 100) 31.33 ; Elec. Cond. at 0° C. (Mercury = 1) 20.97.

Chief ores : Bauxite, Cryolite and the various Felspars. Is a constituent of all clays. First isolated in 1828 by F. Wohler. Given its name by H. Davy from the Latin *alumen*, alum, on account of its presence in the various alums. Owing to difficulties in manufacture, the metal was not commercially marketed until about 1887.

Aluminium is a bluish-white metal capable of taking a high polish. Exposed to air, it becomes covered with a fine film of oxide. By suitable electro-chemical treatment it may be "anodized" or coated with an artificially-produced film of aluminium oxide, Al<sub>2</sub>O<sub>3</sub>, of great tenacity and fineness. This film may then be dried, thus imparting a coloured surface to the metal. Aluminium is fairly ductile and malleable, particularly above 100° C. At 530° C. the metal becomes so brittle that it can be powdered. When ignited at high temperatures it burns brilliantly, an extremely high temperature being attained. Upon this fact is based the principle of "Thermite" welding. The metal is electrically positive. It dissolves in many acids and also in solutions of caustic soda and potash. Owing to its tendency to form and retain an oxide coating, the metal is difficult to solder. Aluminium forms a large series of alloys with other metals, many of which are nowadays of the greatest importance. Cast aluminium has a tensile strength of about 5 tons per square inch ; when rolled, of about 12 tons per square inch.

**Aluminium Amalgam.**—This is prepared by adding fine aluminium filings to a ½% solution of mercuric chloride for two or three minutes, and afterwards washing the product with alcohol or spirits. The resulting amalgam decomposes water at ordinary temperatures, liberating a steady stream of hydrogen gas.

**Aluminium Brass.**—A variety of copper-aluminium alloys containing up to 5% of aluminium. Uses similar to those of aluminium bronze.

**Aluminium Bronze.**—A class of copper-aluminium alloys containing from 5 to 11% of aluminium. They are chiefly of use in circumstances in which it is necessary to increase the oxidation resistance of the metal. They have tensile strengths up to 38 tons per square inch.

## ALUMINIUM-CHROMIUM ALLOY

**Aluminium-Chromium Alloy.**—Alloyed with chromium, aluminium forms beautiful needle-like crystals. The alloy is brittle, however, and has no commercial applications.

**Aluminium Gold.**—A peculiar alloy having an intense ruby-red colour. Composition : aluminium, 22% ; gold, 78%. M.P. 1060° C.

**Aluminium Steel.**—Aluminium is not usually alloyed with steel in order to form a special alloy, but in view of its deoxidizing powers. Dissolved oxides in molten steel tend to form blow-holes.

Aluminium steels were first investigated by Sir Robert Hadfield in 1890. With steel containing, say, 0.2% of carbon, aluminium may be added in amounts up to 5% without influencing the tensile strength. The brittleness of the steel, however, increases with more than 2% of alloyed aluminium.

There is a curious alloy formed with iron and about 17% of aluminium. This is non-magnetic and heat-resisting.

**Aluminum.**—The American rendering (pronounced “a-loo-mu-num”) of our word “aluminium.” It is, perhaps, the more logical word, since it more clearly indicates the fact that the metal is a constituent of alum.

**Alumium.**—An early name for aluminium suggested by Sir Humphry Davy in 1807.

**Alunite.**—A mineral which is often the source of aluminium and potash. Chemical symbol,  $K_2Al_6(OH)_{12}(SO_4)$ .

**Amalgam.**—The name given to a solution of a metal in mercury or to an alloy of mercury with one or more metals. Most metals will form an amalgam with mercury, and often, as in the case of sodium and potassium, the amalgamation is accompanied by considerable rise of temperature. In other instances, as, for example, in the preparation of tin amalgam, there is an absorption of heat during the process of amalgamation.

Amalgams are much used in modern industry and arts, as, for instance, in the extraction of gold and for the filling of teeth.

**American Gold.**—American standard gold as used for coinage purposes contained 90% of gold and 10% of copper, thus being slightly harder than the English standard gold on account of its increased copper content.

**American Nickel-Silver.**—An old alloy. It contained : iron, 1 part ; cobalt, 1 part ; silver, 2 parts ; tin, 2 parts ; manganese, 4 parts ; nickel, 24 parts ; zinc, 36 parts ; copper, 96 parts.

**A.M.F. Alloy.**—This contains 57% of nickel and has the same thermal expansion as steel but is more stable and less liable to corrosion.

**Ammonium Amalgam.**—When a quantity of sodium amalgam is thrown into a dish containing a fairly strong solution of ammonium chloride (*sal ammoniac*), the mercury swells up

enormously into a metallic-looking, soft, sponge-like mass. This is often called "ammonium amalgam," and it has been thought to consist of a true amalgam of mercury with the "ammonium" group or radical ( $NH_r$ ). It is now believed to comprise merely mercury, which is inflated by hydrogen gas, for, after a few minutes, the mass sinks down again, leaving metallic mercury at the bottom of the dish.

**Amorphous Antimony.**—A black powder produced by the electrolysis of a solution of tartar emetic in antimony trichloride. It consists of metallic antimony mixed with from 4 to 12% of antimony trichloride.

Amorphous antimony is unstable, and will return to the more usual crystalline form of antimony with explosive violence when merely scratched or given a slight blow. On this account, it is often known as "explosive antimony."

**Anatomical Alloy.**—An alloy which is sometimes used for taking casts of certain portions of the human and animal body, such as an ear, after death. It melts at  $169^{\circ}$  F. and remains liquid at  $140^{\circ}$  F. Composition: bismuth, 53.5%; lead, 17.0%; tin, 19.0%; mercury, 10.5%.

**Anglesite.**—One of the principal minerals found in oxide lead ore. Chemical symbol,  $Pb SO_4$ . 68.3% Pb.

**Anka Steel.**—A type of stainless chrome-nickel steel containing about 15.5% of chromium and 10% of nickel. It is a well-known Sheffield steel.

**Annabergite.**—One of the nickel salts. Chemical symbol,  $Ni_3(AsO_4)_2 + 8H_2O$ .

**Annealing.**—The process of heating and cooling a metal or alloy from bright red heat (or other suitable temperature) down to ordinary temperature. It usually increases the softness and malleability of a metal. The term also applies to process annealing, normalising, tempering, etc.

**Anodised Aluminium.**—Aluminium which has been made the anode or positive electrode of an electrolytical chemical bath containing sodium phosphate or other solution. On passing a current through such a bath, the aluminium is chemically oxidised on the surface. (See **Aluminium**.)

**Anticorodal.**—A modern aluminium alloy of Swiss origin. Composition: magnesium, 0.6%; silicon, 1.0%—remainder aluminium. It can be heat-treated and has a tensile strength of approximately 20 tons per square inch.

**Anti-friction Metals.**—Name given to various alloys which are employed for the provision of high-speed bearings. Owing to the softness of the alloys, they stand up to friction well—hence the name "anti-friction"—and they are also able to withstand heavy pressures. A common practice is to make the foundation of the bearing of brass or bronze and then to

## ANTIMONIAL LEAD

line this with the anti-friction metal. This practice has the advantage of enabling the bearing to be readily renewed merely by melting-out the anti-friction metal.

In the preparation of anti-friction metals, alloys containing copper, tin, lead, antimony, zinc are used, but it is seldom that more than three of these metals enter into the composition of any one alloy.

Owing to the white appearance of these anti-friction metals, they are frequently termed "White metals."

**Antimonial Lead.**—Lead containing antimony.

**Antimony.**—Metallic element. Chemical symbol, Sb (from the Latin *stibium*). At. No. 51; At. Wt. 120; M.P. 629.2° C.; B.P. 1440° C.; Sp. Grav. 6.7; Sp. Ht. 0.0495; Coef. Exp. 0.0000012; Therm. Cond. (Silver = 100) 4.03; Elec. Cond. at 0° C. (Mercury = 1) 2.05. Chief ores: Stibnite,  $Sb_2S_3$ ; Antimony bloom,  $Sb_2O_3$ ; and Antimony blend,  $Sb_2O_3.2Sb_2S_3$ . Also occurs in free metallic state. Antimony was known in medieval times, its preparation being described by Basil Valentine, a Benedictine monk, in 1413. The meaning of the name "antimony" is not known, but it has been supposed to be derived from the Greek *anti*, against; *nomos*, the law.

Antimony is a silvery-white metal having a pronounced crystalline structure. Very brittle and easily powdered. A poor electrical conductor. Does not readily tarnish in dry air, but becomes covered with a film of oxide in moist air. All antimony compounds are highly poisonous. When molten antimony solidifies, it expands very slightly. Hence the metal is useful in alloys such as type-metal, etc., from which fine and sharp castings are to be made. Chemical science has shown that antimony can exist in several different forms, such as **Yellow** and **Black Antimony** (which see). The metal is attacked by most mineral acids and is chemically closely related to arsenic on the one hand and bismuth on the other.

It is used principally in the making of casting alloys.

**Aphfit.**—An iron-nickel alloy containing tungsten and copper. Composition: iron, 66 parts; nickel, 23 parts; copper, 5 parts; tungsten, 4 parts.

**Ardal.**—An aluminium alloy of British origin. Contains: copper, 2%; iron, 1.7%; nickel, 0.6%—remainder aluminium.

**Ardaloy.**—One of the commercial brands of cemented carbides. (See **Tungsten Carbides and Powder Metallurgy Carbides.**)

**Argasoid.**—An imitation silver. Composition: tin, 4 parts; lead, 3.5 parts; copper, 55.5 parts; zinc, 23 parts; nickel, 13.5 parts; together with a trace of iron.

**Argentan.**—A nickel or German silver.

**Argentiferous Lead.**—Lead containing a small proportion of silver, as it often does in the natural state. (From the Latin *argentum*, silver.)

**Argentine Metal.**—A bright-looking tin alloy sometimes used for making toys, etc. Composition: tin, 85.5% ; antimony, 14.5%.

**Argentite.**—Mineral containing silver. Chemical symbol,  $\text{Ag}_2\text{S}$ .

**Argent-ruolz.**—(Ruolz's silver.) A series of alloys patented in France by M. Ruolz in 1853. Composed of silver, nickel and copper. Very similar to silver in appearance.

**Arguzoid.**—A white nickel-silver metal of composition: nickel, 20½% ; copper, 48½% ; zinc, 31%. Used as a solder for nickel-silver articles.

**Argyrodite.**—A silver-bearing ore.

**Armco Iron.**—A nearly pure iron. It contains under 0.1% of impurity.

**Arsenic.**—Semi-metallic element, often referred to as a *Metalloid*. Chemical symbol, As ; At. No. 33 ; At. Wt. 75 ; Sublimes slowly without melting, but if heated under pressure melts at 817° C. ; Sp. Grav. 5.727 ; Sp. Ht. 0.083 ; Coef. Exp. 0.0000059 ; Elec. Cond. at 0° C. (Mercury = 1) 2.679. Chief ores: Realgar,  $\text{As}_2\text{S}_3$  ; Orpiment,  $\text{As}_2\text{S}_3$  ; Arsenical pyrites ; Mispickel ; Mundic,  $\text{FeS}_2\text{FeAs}_2$ . Also occurs in free state. Arsenic was known to the ancient Greeks, its name being derived from the Greek *arsenicon*, meaning "potent." Arsenic is a steel-grey metal or "metalloid" which, when sublimed, forms lustrous hexagonal rhombohedral crystals. Like antimony, it can exist in several different forms or "allotropic modifications," such as **Grey Arsenic**, **Yellow Arsenic**, etc. (which see). When ordinarily heated, arsenic does not melt, but passes off as a garlic-smelling vapour. Arsenic and all its compounds are exceedingly poisonous, but many of the latter are used in medicine. Chemically, arsenic is a reactive element. As a metal, however, it is useless, except, perhaps, for alloying in minute quantities with other metals. Thus, a trace of arsenic (say 1 in 1,000) in lead makes the lead harder. "Chilled shot" is usually hardened with arsenic.

**Arsenical Copper.**—Copper containing small amounts of arsenic. It has, in the past, been employed for locomotive firebox service on account of its supposed lower rate of oxidation. Recently, however, it has been shown that the addition of arsenic to copper actually increases its rate of oxidation, and nickel-silicon-copper alloys have been introduced to replace it. .

**Arsenopyrite.**—(See **Mispickel**.)

## ASBOLAN

**Asbolan.**—Earthly cobalt. A hydrated oxide of manganese, iron, and cobalt.

**Ascoloy.**—A chromium steel alloy—**Rustless Iron** (which see).

**Ashberry Metal.**—A type of Britannia metal. Composition: tin, 80% ; antimony, 14% ; copper, 2% ; zinc, 1% ; nickel, 3%.

**Ash Metal.**—A very low-grade brass alloy made from metal skimmings and ash from brass foundries.

**Atelestite.**—Bismuth arsenate. Chemical symbol,  $H_2Bi_3AsO_8$ .

**Atmalloy.**—A powder iron used for the manufacture of telephone repeater coils and wireless inductances. (See **Ferrocart**.)

**Auer Metal.**—An alloy of iron and cerium metals, similar to **Mischmetal** (which see). It is a pyrophoric metal and emits a bright shower of sparks when struck. Used in automatic lighters, etc. It was introduced into commerce by Dr. Carl Auer (later Baron Auer von Welsbach), the inventor of the incandescent gas mantle. Hence its name.

**Austenite.**—Name given to a solid solution of carbon in iron. Named after W. C. Roberts-Austen, the metallurgist. Steels containing austenite are termed "austenitic."

**Austenitic Steel.**—(See **Austenite**.)

**Australian Gold.**—The standard gold coinage of Australia (as minted at Sydney) contained 91.66% of gold and 8.33% of silver, thus giving to the Australian gold coinage its characteristic greenish-yellow appearance. In English standard gold the silver is replaced by copper.

**Autogenous Soldering.**—The uniting of two pieces of metal together simply by melting their edges by means of a blow-lamp or other source of heat. The word "autogenous" means "self-generated."

The lead linings of chemical and acid tanks are usually autogenously soldered because the presence of any dissimilar metal at the joints would set up electrolytic actions which might attain serious proportions.

**Avional.**—A Swiss aluminium alloy. Composition: copper, 4.75% ; magnesium, 0.5% ; manganese, 1.0% ; silicon, 1.4% —remainder aluminium. Is hard and enduring. Tensile strength about 30 tons per square inch.

**Azurite.**—One of the copper minerals found in the oxide ores. Chemical symbol,  $2CuCO_3 \cdot Cu(OH)_2$ . 51.1% Cu.

## B

**Babbit's Metal.**—The original alloy recommended by Babbit was made up of the following ingredients: copper, 4 lb. ; antimony, 8 lb. ; tin, 24 lb. To every pound of the above, 2 lb. more of tin was added.

Many soft lining and anti-friction bearing metals have subsequently borne the name of "Babbit," but the above is the original alloy devised by Babbit himself.

**Baddeleyite.**—A mineral in which zirconium occurs. Chemical symbol,  $(\text{ZrO}_2)$ .

**Bahnmetall.**—"Railway Metal." A soft bearing metal used on the German State Railways for the linings of axleboxes. Was introduced during the Great War (1914-18) and is still used with, it is said, excellent results. It consists of lead alloyed with small amounts of sodium, calcium and lithium. Approximate composition: sodium, 0.58-0.62%; calcium, 0.69-0.73%; lithium, 0.04%—remainder lead. It has a Brinell hardness of about 34, and a compressive strength of between 25,000 and 30,000 lb. per square inch.

**Banka Tin.**—Tin from the Island of Banka, in the Dutch East Indies.

**Barium.**—Metallic element. Chemical symbol, Ba; At. No. 56; At. Wt. 137; M.P.  $850^{\circ}\text{C}.$ ; Sp. Grav. 3.75; Sp. Ht. 0.068. First prepared (in an impure form) by Davy in 1808. Its name is derived from the Greek *baros*, heavy, in reference to the heavy mineral "barote" (afterwards called "baryta") which contains the element.

Chief ores: Heavy spar, Barytes,  $\text{BaSO}_4$ , Witherite,  $\text{BaCO}_3$ . Barium, when pure, is a silvery, lustrous metal, having a yellow tinge. It has rarely been obtained in the pure state, however, owing to the extreme difficulty of its preparation. It tarnishes rapidly in air, becoming coated with a film of oxide. It decomposes water with the evolution of hydrogen and the formation of barium hydroxide,  $\text{Ba}(\text{OH})_2$ .

As a metal, barium has no uses whatever, although its chief ore, barytes, is of great value in industry. Alloys of barium with lead, aluminium, bismuth and antimony have been reported from time to time. Barium is closely related in chemical properties to calcium and strontium.

**Base Metals.**—(See **Noble Metals.**)

**Bath Metal.**—An alloy which was at one time very popular in England for the manufacture of teapots, sugar-basins and other tableware. It is silvery-white in colour, and takes a high polish. Composition: copper, 55 parts; zinc, 45 parts.

**Baudoin's Alloy.**—An imitation silver. Composition: copper, 72%; nickel, 16.6%; cobalt, 1.8%; tin, 2.5%; zinc, 7.1%. Sometimes about 0.5% of aluminium is also added.

**Bauxite.**—General name given to the hydrated oxides of aluminium.

**Bearing Metals.**—(See **Anti-friction Metals.**)

**Bell Bronze.**—A class of cast copper-tin alloys containing from 20 to 25% of tin. These alloys are hard and brittle and it

## BELL METAL

is claimed that no other alloy possesses the tone characteristics shown by them.

**Bell Metal.**—A type of bronze or copper-tin alloy containing from 12% to 24% of tin. Technically known as "Hard Bronze."

**Beryl.**—(See **Beryllium.**)

**Beryllium.**—Formerly named "Glucinum." Metallic element. Chemical symbol, Be ; At. No. 4 ; At. Wt. 9 ; M.P. 1280° C. ; Sp. Grav. 1.83 ; Sp. Ht. 0.397.

Chief ore : Beryl,  $3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ . Occurs also in gems, such as emerald.

Name of the metal derived from its principal ore, *beryl*. Beryllium was first isolated in an impure form by F. Wöhler in 1827. Not prepared in a pure state until 1885, and until very recent times it has remained an uncommon metal. Nowadays, however, beryllium is rapidly attaining a status of commercial importance, as a light alloying metal, particularly in America.

Beryllium is a white metal resembling magnesium in appearance but being considerably lighter in weight. Next to lithium, beryllium is the lightest metal known. It is fairly malleable, and remains unchanged in ordinary air, even when heated. Powdered beryllium, however, when heated, burns much in the same manner as magnesium, emitting a brilliant light.

Beryllium is acted upon by mineral acids and bears a close chemical resemblance to magnesium. It has now become an important alloying metal, and it may yet be employed in the pure state in view of its extreme lightness, provided that its manufacture can be cheapened sufficiently.

**Beryllium-Cobalt-Copper.**—A high-conductivity copper alloy, not unlike beryllium-copper, but containing 0.4% beryllium, 2.6% cobalt, balance copper. Has an average tensile strength of 95,000 lb. per square inch.

**Beryllium Copper.**—A copper-beryllium alloy containing from 1.5 to 2.75% of beryllium, the standard alloy having a beryllium content of 2.25. Sometimes up to 0.5% of nickel is added to these alloys to restrict grain size during annealing. They were originally investigated by Dr. G. Masing in 1926 and are now of much commercial interest.

In the annealed condition, the standard beryllium-copper alloy has a tensile strength of 70,000 lb. per square inch, whilst by cold rolling and heat-treatment, its tensile strength can be still further increased. The alloy is obtainable in rod, strip, sheet or cast form. It is now being much used for the production of springs, which show remarkable endurance properties, and, also, for the making of non-sparking tools. With the gradual cheapening of metallic beryllium, beryllium-copper alloys have a promising future.

**Beryllium Gold.**—Gold-beryllium alloys containing from 0.5 to 5% of beryllium have been worked out in America. When the beryllium content exceeds the former percentage, however, they become too brittle to work, the beryllium exerting an extreme hardening effect upon the gold. Some of these alloys have been used as gold solders and dental inlays.

**Beryllium Silver.**—An alloy of silver and beryllium containing from 0.41 to 0.90% of beryllium.

**Beryllium-Silver-Copper.**—A group of copper alloys recently introduced in America. Typical composition: silver, 70.44%; copper, 28.90%; beryllium, 0.87%. Used as a resistance-wire material.

**Bessemer Steel.**—Steel manufactured by the Bessemer process (the invention of Sir Henry Bessemer in 1856). In the Bessemer process, the molten "pig" iron is run into a receptacle known as a "converter," in which a blast of air is passed through it. Thus impurities are burned out of the molten metal.

**Beta Iron.**—Between 900° C. and 768° C. iron is known as Beta Iron. (See **Alpha, Delta** and **Gamma**.)

**Bitra Alloy.**—Composition: bismuth, 8 parts; tin, 9 parts lead, 38-40 parts.

**Bidery Metal.**—An alloy which was at one time very popular in India. It was first manufactured at Bidar, near Hyderabad, in India, from which town it takes its name. The metal does not easily tarnish or oxidise, and was at one time employed for the manufacture of Indian cooking vessels. Its composition (average) is: tin, 1.4%; copper, 11.4%; zinc, 84.3%; lead, 2.9%.

**Billet.**—A short, thick metal bar which is used for forging or rolling.

**Bimetal.**—Name given to two dissimilar metals sweated or fused together so as to make up a composite metal sheet. Nowadays, bimetals are much used in consequence of the unequal rates of expansion of their constituent metals causing the bimetal to curl when heated and thereby enabling a temperature-measurement to be made or an electrical circuit to be opened or closed at a definite temperature.

**Binary Alloy.**—An alloy containing two constituent metals.

**Binary Steels.**—These are alloy steels containing one special alloying metal, as, for instance, chromium steel.

**Birmabright.**—An aluminium-magnesium alloy containing about 7% magnesium (and sometimes 1% of manganese). Can be worked easily and is resistant to atmospheric tarnishing and corrosion.

**Birmasil Special Alloy.**—An aluminium alloy containing from 10 to 13% of silicon and from 2.5 to 3.5% of nickel, in addition

## BIRRIDIUM

to small amounts of copper, iron and manganese. It has a good resistance to corrosion and a high tensile strength. It is tough and ductile.

**Birnidium.**—An aluminium alloy produced in Birmingham. Hence its name. It has a composition and properties similar to "Y" Alloy (which see).

**Birmingham Platinum.**—A white brass of variable composition. The following is typical: copper, 43%; zinc, 57%. Also known as "Platinum Lead." This alloy was formerly used for casting buttons.

**Bismuth.**—Metallic element. Chemical symbol, Bi; At. No. 83; At. Wt. 208; M.P. 269° C.; B.P. 1420° C.; Sp. Grav. 9.823; Sp. Ht. 0.0305; Coef. Exp. 0.00001333; Therm. Cond. (Silver = 100) 1.8; Elec. Cond. at 0° C. (Mercury = 1) 0.8676.

Chief ores: Bismuth ochre,  $Bi_2O_3$ ; Bismuth glance,  $Bi_2S_3$ . It occurs mainly in the free metallic condition.

Metallic bismuth was known by the alchemists, but was frequently confused with antimony and/or zinc. The metal was, perhaps, first scientifically studied by an Englishman, J. H. Pott, in 1739. Its name is supposed to be derived from the German *weissmuth*, white matter, in reference to its now well-known white carbonate.

Bismuth is a white, lustrous metal having a very faint reddish tinge. It is extremely brittle and is a poor conductor of heat and electricity. Alloys readily with other metals, and imparts to them the properties of hardness and low-temperature fusibility. Hence, it is used a good deal in the making of such alloys as Wood's metal, etc. "Fusible metals" of this type are used as safety plugs in steam boilers, in fire-alarm apparatus and in other devices. Bismuth alloys are also used for the making of metallic casts. Chemically, bismuth is fairly reactive, its best-known compound, bismuth carbonate, being a popular medicinal substance. In most of its properties, bismuth is similar to antimony.

**Bismuth Amalgam.**—A thinly fluid amalgam prepared by adding mercury to molten bismuth. Almost any proportions of these two ingredients may be used. Bismuth amalgams, on account of their fluidity, are useful for filling very delicate moulds. Other amalgams are also rendered more fluid by adding to them a small proportion of a bismuth amalgam.

Bismuth amalgam is sometimes used for silvering glass globes and similar articles.

The amalgam will pass through chamois-leather like mercury. The drops, however, are pear-shaped and not perfectly globular as in the case of pure mercury.

**Bismuth Bronze.**—An alloy sometimes used for mirrors and

## BONDERISING, COSLETTISING AND PARKERISING

lamp reflectors on account of the very high polish which it takes. Composition: copper, 52 parts; nickel, 30 parts; zinc, 12 parts; lead, 5 parts; bismuth, 1 part.

**Bismuth Purissimum.**—Name sometimes given to refined bismuth metal of from 99.85 to 99.98% purity.

**Bismuthinite.**—Bismuth sulphide. Chemical symbol,  $\text{Bi}_2\text{S}_3$ .

**Bismutite.**—Bismuth Carbonate. Chemical symbol,  $\text{Bi}_2\text{O}_3 \cdot \text{CO}_2 \cdot \text{H}_2\text{O}$ .

**Black Antimony.** (See **Yellow Antimony.**)

**Black Arsenic.**—Also known as "beta" arsenic. Obtained by the slow condensation of arsenic vapour. It occurs as a black powder or a brittle, glassy-looking mass which, when heated to  $360^\circ\text{C}$ ., passes into the ordinary "grey" or "metallic" arsenic.

**Black Tin.**—Strictly speaking, this is not a metal. It is the name given by miners to tinstone (tin ore) to distinguish it from tin metal which they called "White tin".

**Blende.**—(See **Sphalerite.**)

**Blister Copper.**—Name given to metallic copper after it has been roasted in a reverberatory furnace. It has then a blistered appearance.

**Blister Steel.**—(See **Cementation Steel** and **Crucible Steel.**)

**Block Tin.**—Name given to ingots of cast tin. These are usually cast in granite moulds.

**Blowhole.**—An air-hole in a metallic casting.

**Blue Gold.**—(a) A gold-iron alloy containing from 25 to 33.3% of iron.

(b) A colloidal solution of gold prepared by reducing a solution of gold chloride with hydrazine hydrate. It possesses a bluish colour.

**Blue Metal.**—A name for impure copper obtained during the process of copper smelting. "Blue metal" contains from 55 to 66% of metallic copper mixed with copper and iron sulphides. It has a peculiar bluish colour.

**Bob Brass.**—(See **Ferrule Brass.**)

**Bobierre's Metal.**—This is ordinary brass consisting of 66 parts of copper and 34 parts of zinc. Introduced by M. Bobierre in the last century as a sheathing for ships.

**Bonderising, Coslettising and Parkerising.**—These are varieties of a general method of developing a film of ferrous phosphate on the surface of the part to be treated. These parts are immersed in a hot bath of a solution of ferrous phosphate (about 2½%) with other salts such as manganese phosphate. Sometimes copper salts and various metallic nitrates are added. The film developed by these processes affords a certain amount of protection against corrosion, but the chief merit is the bond it offers to enamels, thus avoiding

## BOROTO METAL

those objectionable patches which sometimes show themselves on enamelled surfaces. A cheaper form of this treatment is to spray a solution of zinc phosphate on to the surface and after washing in water to apply hot dilute chromic acid.

**Boroto Metal.**—A tin-lead-antimony whitemetal in which colloidal graphite is incorporated. Of American origin, it has a Brinell hardness of from 17 to 25, and is employed as self-lubricating bearing metal.

**Bornite.**—One of the sulphide ores of copper, sometime known as peacock ore. Chemical symbol,  $Cu_3FeS_3$ . 55.5% Cu.

**Bottger's Amalgam.**—An electric amalgam used in frictional machines, etc. Composition : zinc, 2 parts ; mercury, 1 part.

**Bottoms Copper.**—The copper which has sunk to the bottom of the smelting furnace. It is the least pure of the mass of metal in the furnace and it usually contains tin, lead and antimony, and sometimes traces of silver and gold.

**Bourbon Metal.**—An alloy composed of equal parts of tin and aluminium. It solders readily.

**Bower-Barffing Process.**—In this process iron or steel is made red hot and exposed to superheated steam in a closed chamber. This causes a film of black magnetic oxide of iron to be formed on the surface, which affords a considerable measure of protection against rust.

**Brass.**—A generic name given to alloys of copper and zinc. Common brass (or cast brass) contains 2 parts of copper and 1 part of zinc.

Brass has been known from early ages. Its name is supposed to be derived from the Anglo-Saxon word *brae*, a fire-produced metal.

The various brasses are described under their individual names.

**Braunite.**—Manganese mineral. Chemical symbol,  $Mn_2O_3$ .

**Brazing.**—Soldering with a brass alloy.

**Brazing Brass.**—A brass alloy having a low zinc content. It possesses a red colour and is used for brazing purposes. Composition : copper, 86.75 parts ; zinc, 12 parts ; lead, 1.25 parts.

**Brazing Metal.**—This term is usually synonymous with brazing brass.

**Brazing Solder.**—A variety of brass containing : copper 50% ; zinc, 50%. Is usually cast in iron moulds having transverse and longitudinal ridges, so that the cake of brass can be broken up into small rectangular pieces. These pieces are then heated in a furnace and afterwards powdered in an iron mortar. The solder is used for uniting iron and brass.

**Brearley Steel.**—An original type of stainless steel discovered in 1913 by Mr. Harry Brearley, of Sheffield. It is a high chromium steel and it was first made available for cutlery purposes about the middle of 1914.

## BRONZE POWDERS

**Breithauptite.**—One of the nickel arsenides. Chemical symbol, NiSb.

**Brightray.**—A nickel-chromium alloy of high corrosion resistance.

**Brinell Hardness Test.**—A standardized test of metal hardness. It is made by indenting the smooth surface of the metal under test by means of a hardened steel ball (usually 10 mm. in diameter) by subjecting it to a pressure or load of 300 kilograms for a soft metal and 3,000 kilograms for a hard metal. For very hard materials, a 2-mm. diameter diamond sphere is used.

By means of a lens, the diameter of the indentation in the metal surface is measured, and this is used as a means of calculating comparative hardness numbers.—Brinell hardness numbers, see page 168.

**Bristol Brass.**—This is the same as **Prince's Metal** or **Mannheim Gold** (which see).

**Britannia Metal.**—This is, in reality, tin hardened with from 5 to 10% of antimony. It frequently contains a small amount of copper. Typical composition is: tin, 140 parts; antimony, 8 parts; copper, 3 parts. An increase in the amount of copper has the effect of colouring the metal.

The average M.P. of the above alloy is 250° C. It is much used as the base metal of plated goods of the ornamental type.

**Brittleness.**—A metal which easily breaks upon the application of a sudden shock or one which fractures readily when subjected to a hammering or compressing force is considered to be brittle. Metals are usually increased in brittleness by the presence of impurities within them. Thus phosphorus in iron renders the metal brittle or "short."

Crystalline metals are usually brittle, because of the feeble degree of cohesion between their component crystals.

Distinguish carefully between brittleness and hardness of a metal. The two terms are by no means synonymous. Thus, for example, manganese steel is hard, but it is not brittle. Metallic tellurium is brittle but it is not hard.

**"Brocade."**—A type of bronze powder consisting of coarse metal flakes prepared from the waste of metal-leaf factories.

**Bronze.**—The name given to a large class of copper-zinc-tin alloys. Approximate limiting proportions of these constituents are: copper, 70–90%; zinc, 1–25%; tin, 1–18%.

Such bronzes are much used for making castings, coins, ornaments, etc.

Bronze has been known from very ancient times.

**Bronze Powders.**—These are used for coating metallic and non-metallic objects in order to impart to them a decorative appearance. They have the following average composition: copper, 64–83%; silver, 4·3–4·5%; tin, 8–8·7%. The lower grades

## BROWN GOLD

of bronze powders contain up to 13% of zinc, which whitens them considerably.

**Brown Gold.**—An alloy containing 20 parts of gold, 4 parts of copper.

**Brucite.**—One of the minerals producing magnesium. Chemical symbol,  $MgO \cdot H_2O$ .

**Buflokast.**—An iron-silicon alloy of American origin. It is non-corrosive and is similar to **Tantiron** (which see).

## C

**Cadmium.**—Metallic element. Chemical symbol, Cd ; At. No. 48 ; At. Wt. 112 ; M.P.  $320.2^{\circ}C.$  ; B.P.  $745^{\circ}C.$  ; Sp. Grav. 8.6603 ; Sp. Ht. 0.0548 ; Coef. Exp. 0.00003323 ; Therm. Cond. (Silver = 100) 20.06 ; Elec. Cond. at  $0^{\circ}C.$  (Mercury = 1) 13.46.

Occurrence : Mainly in zinc ores. Cadmium never occurs in Nature in the free state.

Cadmium was discovered by F. Stromeyer in 1817 in a specimen of zinc carbonate, the name "cadmium" being coined from the term *cadmia fossilis*, by which zinc ores was then known, the ancient Greeks having, during their civilization, known zinc ore as "cadmeia."

Cadmium is a bluish-white metal, closely related to zinc on the one hand and to mercury on the other. It tarnishes superficially, and is fairly reactive chemically, one of its chief compounds, cadmium sulphide,  $CdS$ , being extensively employed in the paint industry as a golden-yellow pigment.

Cadmium metal is ductile, and can be rolled into sheets and drawn into wire. It has been used to some extent as a plating metal. Cadmium is also used in the making of fusible alloys and certain casting metals.

**Cadmium Amalgam.**—Amalgams of mercury and cadmium readily crystallize. They can be made in almost any proportions. They are tin or silver-white in colour and, when heated, become soft and can be kneaded. These amalgams are useful as metallic fillings and stoppings for a variety of purposes.

When mercury is completely saturated with cadmium, the resulting amalgam has the composition : mercury, 78.26 parts ; cadmium, 21.74 parts. This amalgam is tin-white, crystalline, and, although it is somewhat brittle, it softens, like all cadmium amalgams, when heated, so much so that it can be kneaded like wax. This amalgam is sometimes used by dentists for filling teeth.

**Cadmium Copper.**—A copper-cadmium alloy containing between 0.5% or 1% of cadmium. It was first introduced in

1920 and has an approximately 50% greater tensile strength than ordinary hard-drawn copper wire.

**Cæsium.**—Metallic element. Chemical symbol, Cs ; At. No. 55 ; At. Wt. 133 ; M.P. 26° C. ; B.P. 670° C. ; Sp. Grav. 1.88 ; Sp. Ht. 0.0522.

Discovered by Robert Bunsen and G. Kirchhoff (1860) in certain spring waters containing lithia. Given the name cæsium, from the Latin *caesius*, sky-blue, in respect of the blue light emitted by its incandescent vapour.

Occurrence : in certain mineral waters containing lithia, sodium, etc. Also in some rare minerals.

Cæsium is a silvery-white, ductile metal, which is soft enough to be cut with a knife, like cheese. It is the most electro-positive of metals. Exposed to air, it rapidly becomes covered with a film of oxide, and hence must be preserved below the surface of oil. Like sodium and potassium, it energetically decomposes water with the evolution of hydrogen gas and the production of cæsium hydroxide. If placed in an atmosphere of dry oxygen, cæsium will spontaneously take fire.

Within the last few years, cæsium has come into prominence as a light-sensitive metal in the manufacture of photo-electric cells, "cæsium cells" being particularly infra-red sensitive.

**Calamine.**—One of the zinc oxide ores. Chemical symbol,  $2\text{ZnSiO}_3 + \text{H}_2\text{O}$ . 57.1 Zn.

**Calamine Brass.**—An early type of brass which was made by heating copper, calamine (zinc carbonate) and charcoal. It was known before the discovery of zinc.

**Calaverite.**—Mineral from which gold and tellurium are extracted. Chemical symbol,  $\text{AuTe}_2$ .

**Calcium.**—Metallic element. Chemical symbol, Ca ; At. No. 20 ; At. Wt. 40 ; M.P. 780° C. ; Sp. Grav. 1.52 ; Sp. Ht. 0.152 ; Elec. Cond. at 0° C. (Mercury = 1) 12.5.

Discovered in 1808 by H. Davy. Name derived from the Latin *calx*, lime, since calcium is the constituent metal of lime and limestone. Occurrence : in limestone, chalk, marble, calc spar,  $\text{CaCO}_3$ .

A white, lustrous metal, having a slight yellow tinge. Has a strong affinity for oxygen, becoming coated with an oxide film when exposed to air. Decomposes water with evolution of hydrogen and formation of calcium hydroxide,  $\text{Ca}(\text{OH})_2$ . In general properties calcium closely resembles barium and strontium. When heated in nitrogen, forms calcium nitride,  $\text{Ca}_3\text{N}_2$ . Calcium metal is fairly soft and malleable. Usually preserved under oil or naphtha.

Calcium metal can be made to form alloys with aluminium, lead, antimony, sodium, potassium and zinc, as well as several

## CALCIUM LEAD

amalgams with mercury, but neither the metal nor its alloys have any special uses.

**Calcium Lead.**—Lead containing a small percentage of metallic calcium to harden it.

**Calite.**—A nickel-aluminium alloy used for carburising boxes, etc. It is heat-resisting.

**Calorising.**—A method of applying a coating of high aluminium content to steel or iron articles. The objects are sealed in a rotating drum containing a mixture of powdered aluminium, aluminium oxide and ammonium chloride. In this they are heated to a temperature of about 1700° F. in an atmosphere of an inert gas such as nitrogen.

Sometimes, after removal from the drum, the steel or iron objects are submitted to further heat treatment in order to diffuse the aluminium coating through the deeper layers of the metal and thereby to increase the protective value of the coating which they have acquired.

Usually, the protective coating produced on steel or iron articles by calorising consists of an intermetallic compound of iron and aluminium.

**Camelia Metal.**—A white metal used for pivot bearings in machinery and for similar purposes. Composition : zinc, 10.2% ; copper, 70.2% ; tin, 4.25% ; lead, 14.75% ; iron, 0.55%.

“**Carat**” **Gold.**—The amount of gold in alloys is conventionally expressed in parts per 24, these parts being termed “carats.” Thus pure gold is “24 carat gold,” whilst a gold alloy containing 18 parts of gold and 6 parts of silver (or copper) constitutes “18-carat gold.” Similarly, “9-carat gold” contains 9 parts of gold and 15 parts of other metal.

The word “carat” is supposed to be derived from the Greek *keration*, signifying a bean or a seed used for weighing gold. Carat is also the unit of weight for gems.

**Carbide, Cemented.**—(See **Tungsten Carbide.**)

**Carboloy.**—One of the American commercial brands of cemented carbides. (See **Cemented Carbides.**)

**Carbon Bronze.**—An anti-friction bearing metal containing a trace of carbon. Composition : copper, 75.47% ; tin, 9.72% ; lead, 14.57% ; carbon, 0.1%.

**Carbondale Silver.**—A variety of nickel silver. Composition : copper, 66 ; nickel, 18 ; zinc, 16.

**Carbon Steel.**—Roughly speaking, steel is an intermediate material between cast iron and wrought iron, the latter being the purest form of iron commercially attainable.

Cast or pig iron contains about 3% of carbon. Wrought iron contains about 0.06% of carbon. Between these two limits comes “steel,” a form of iron containing dissolved or

alloyed carbon. "Carbon steel," therefore, is nothing more nor less than "ordinary" steel, the word "carbon" being employed to distinguish the metal from the nowadays numerous "alloy" or "special" steels which contain other alloying metals in addition to carbon. "Carbon" steel, therefore, is the "old-fashioned" type of steel.

A "hard" carbon steel contains about 1% of carbon, whilst a "soft" steel of this type has a carbon content of about 0.1%.

**Carnallite.**—A mineral yielding magnesium. Chemical symbol,  $MgCl_2 \cdot KCl \cdot 6H_2O$ .

**Carnotite.**—A mineral from which vanadium is produced. Chemical symbol,  $K_2O \cdot 2UO_3 \cdot V_2O_5 \cdot 3H_2O$ .

**Cartridge Brass.**—Composition: copper, 63%; zinc, 37%. This composition represents the extreme limit of solubility of zinc in copper. The alloy is more brittle than copper.

**Case-Hardening.**—This consists in impregnating the surface of steel with carbon so that this portion may be hardened by quenching, while the interior remains tough and soft. The steel, as it were, is contained in a hardened "case." There are several ways of case-hardening steel, one of the best-known being to pack the steel objects into a mixture of animal charcoal and barium carbonate and to heat them in a furnace to about 900° C. for a period of time depending upon the depth of "casing" required.

**Cassiopeum.**—A name for Lutecium, proposed by Auer von Welsbach in 1906. It is now obsolete.

**Cassiterite.**—The important mineral of tin, chemical symbol,  $SnL_3$ , which theoretically contains 78.6% Sn. Tungsten minerals are frequently associated with it. The minerals Stannite and Tealite are occasionally found in small quantities.

**Cast Brass.**—A very common brass. It may contain up to 75% of copper, but an average composition is 2 parts of copper to 1 of zinc. It often contains a very small amount of lead. It is often known as "Common Brass."

**Cast Iron.**—Contains about 2% carbon. It is crystalline and brittle. There are various qualities—white cast-iron, malleable cast-iron, grey cast-iron, etc. (See also **Pig-iron**.)

**Cast Steel.**—This term was originally applied only to crucible steels. A high-grade steel, made in converter, open-hearth, electric and rotary furnaces.

**Cathode Copper.**—Electrolytically-refined copper which has been deposited on the cathode of the electrolytic bath of acidified copper sulphate solution. Such copper is usually melted up again in a furnace before being marketed as "electrolytic copper."

**Causul Metal.**—A special grade of alloy cast iron containing

## CEMENT COPPER

nickel, copper and chromium. Similar to "Ni-Resist" (which see).

### Cement Copper.—(See Copper Precipitate.)

**Cementation Steel.**—Steel which has been made by the "cementation" process in which bars of wrought iron are packed into sealed boxes together with charcoal. The resulting material is termed **Blister Steel** (which see).

### Cemented Carbides.—See Powder Metallurgy, and Tungsten Carbide.

**Cementite.**—In a 1.25% carbon steel, carbide of iron is first deposited at about 855° C., and this continues down to 695° C. The iron thus precipitated is known as Cementite in order to distinguish it from the carbide in the Eutectoid. Additionally, the term Cementite is applied to any carbide in steel, even though it may contain manganese, chromium, etc. It is thus a carbide of iron ( $Fe_3C$ ) and is a constituent of most carbon steels.

**Ceralumin.**—A British aluminium alloy. Brinell hardness (when heat-treated) 130–140. Tensile strength 40,000 lb. per square inch. Contains: silicon, 1.2%; copper, 2.5%; magnesium, 0.8%; iron, 1.2%; nickel, 1.5%—remainder aluminium.

**Cerargyrite.**—Horn silver, a mineral yielding silver. Chemical symbol  $AgCl$ .

**Cerium.**—Metallic element. Chemical symbol, Ce; At. No. 58; At. Wt. 140; M.P. 623° C.; Sp. Grav. 6.73; Sp. Ht. 0.04479.

The metal was first isolated by Mosander in 1826 from a mineral which had been named "ceria" in commemoration of the discovery of the planet Ceres (the name being that of the old goddess of tillage and corn) in 1801.

Chief ores: Cerite and Monazite.

Cerium, when pure, is a steel-grey metal, ductile and malleable. In moist air, it is superficially oxidised. Cerium is a strongly "pyrophoric" or spark-emitting metal, both in the pure state and in the form of some of its alloys. On this account it has been greatly used in recent years in petrol-lighters and other similar sparking devices. Its salts are employed in the gas-mantle industry, and, to a small extent, in photography.

**Cerromataix.**—An alloy containing lead, tin and antimony, used for the mounting of dies and punches. A special property is the ability it possesses to be slightly softened by the application of localised heat.

**Cerussite.**—One of the principal minerals found in oxide lead ore. Chemical symbol,  $PbCO_3$ . 77.5% Pb.

**Chalcocite.**—Copper glance, one of the sulphide ores of copper. Chemical symbol,  $Cu_2S$ . 79.8% Cu.

**Chalcopyrite.**—One of the sulphide ores of copper. Chemical symbol,  $CuFeS_2$ . 34.5% Cu.

## CHROME-MOLYBDENUM STEEL

**Charpy's Alloy.**—Anti-friction metal. Composition: tin, 83 parts; copper, 11.5 parts; antimony, 5.5 parts.

**China Silver.**—A silvery-white metal containing: copper, 65.24 parts; tin, 19.52 parts; nickel, 13 parts; silver, 2.05 parts.

**Chinese Bronze.**—Also known as *Shaku-do*. A bronze employed for art metalwork. Varies in composition. The following are typical:—

	I	II
Copper . . . . .	94.61%	95.77%
Silver . . . . .	1.55%	0.08%
Lead . . . . .	0.11%	—
Gold . . . . .	3.73%	4.15%

A similar alloy, known as *Shibu-ichi*, contains:—

Copper, 66.31%

Silver, 33.17%

Iron, 0.52%

(with sometimes a trace of gold).

The gold in these alloys is important, since it enables them to acquire a very beautiful patina when used for art metalwork.

Japanese bronzes have a very similar composition.

**Chinese Silver.**—An imitation silver used in the jewellery trade. Composition: copper, 58%; zinc, 17.5%; nickel, 11.5%; cobalt, 11%; silver, 2%.

**Chinese Speculum Metal.**—A reddish mirror metal. Composition: copper, 80.83 parts; antimony, 8.5 parts.

**Chisel Steel.**—A carbon steel containing 1% of carbon. It is readily forged. Used for chisel-making, large punches, miner's drills, etc. Most chisel steels now contain nickel. (See **Nickel Steel**.)

**Chloanthite.**—One of the nickel arsenides. Chemical symbol,  $\text{NiAs}_2$ .

**Christophle Metal.**—An ornamental copper-nickel alloy. Similar to **China Silver** (which see).

**Chrome-Aluminium Steel.**—A type of steel used sometimes on the Continent on account of its resistance to scaling. Has been used for the tubes of locomotive superheaters, etc. Contains about 6% of chromium and from 1 to 1.5% of aluminium.

**Chromel.**—A chemically-resistant pure nickel-chromium alloy. It is also heat-resistant and is sometimes used for making electric fire elements. Composition: nickel, 80%; chromium, 20%.

**Chrome-Molybdenum Steel.**—Steels of this type are resistant to oxidation. They have mostly been developed on the Continent. An average chrome-molybdenum steel contains from 1 to 1.5% of chromium and about 0.5% of molybdenum.

## CHROME-NICKEL

**Chrome-Nickel.**—A nickel-chromium alloy containing about 23% nickel and 73% chromium. Used in the manufacture of chrome-nickel steels.

**Chrome-Nickel Steel.** (See **Chrome Steel.**)

**Chrome Steel.**—Chromium, when alloyed with steel, acts especially as a hardening agent. Hence chromium or chrome steels are characterised by their very great hardness. It is, therefore, more or less drill-proof.

Combined with nickel or vanadium, chromium steel gives the strongest and the best-wearing of the commercial steels, chrome nickel and chrome-vanadium steels being tough, yet machinable. Hence such steels are used for gears and for the crankshafts of internal-combustion engines and for other engineering components which are continuously subjected to heavy service.

Simple chrome steels are used whenever extreme hardness (without machinability) is required. Thus high-quality files are made from chrome-steel. Chromium steels are also used for bearing balls and races, and for projectiles and shells.

Steels containing more than 12% of chromium are highly resistant to corrosion. They constitute the now very much used "Stainless Steels."

**Chrome Vanadium Steel.**—(See **Vanadium Steel.**)

**Chromite.**—A heavy mineral from which chromium is extracted.

Chemical symbol,  $\text{FeCr}_2\text{O}_4$  or  $\text{FeO} \cdot \text{Cr}_2\text{O}_3$ .

**Chromium.**—Metallic element. Chemical symbol, Cr ; At. No. 24 ; At. Wt. 52 ; M.P.  $1520^\circ\text{C}.$  ; B.P.  $2200^\circ\text{C}.$  ; Sp. Grav. 6.9. Sp. Ht. 0.12. Discovered in 1797 by L. N. Vauquelin, who named it "chromium" (from the Greek *chroma*, colour) on account of the coloured salts which it gives rise to.

Chief ores : Chrome iron ore or Chromite,  $\text{Cr}_2\text{O}_3 \cdot \text{FeO}$  ; Chrome ochre,  $\text{Cr}_2\text{O}_3$ .

Chromium is a steely-grey metal having a pronounced bluish cast, particularly when plated. It is very hard and somewhat brittle. Unacted upon by air at ordinary temperatures. Soluble in mineral acids except nitric acid, in which liquid it assumes the so-called "passive" or inert condition. As a plating metal, chromium is now generally employed. Chromium is of great technical importance in metallurgy on account of its hardening effect on steel. The various alloys of chromium and steel are not only hard but also chemically resistant, as, for example, the now well-known stainless and "chemical" steels.

In the pure metallic state chromium has no uses, it being too hard, brittle and difficult to work.

**Chromium Bronzes.**—These are copper-tin alloys containing

chromium and iron. They are corrosion-resistant and have been used as bearing metals.

**Chromium Steel.**—(See **Chrome Steel.**)

**Chrysochalk.**—Name given to an imitation-gold alloy similar to Mannheim gold. Used in cheap jewellery. Average composition : copper, 90.5 parts ; zinc, 7.9 parts ; lead, 1.6 parts. It has a fine golden colour, but it gradually tarnishes on exposure to air.

**Chrysocolla.**—One of the copper minerals found in the oxide ores. Chemical symbol,  $\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$ . 37.9% Cu.

**Chrysorin.**—An imitation gold. In reality, a variety of brass. Average composition : copper, 66.6% ; zinc, 33.4%.

The name is derived from the Greek *chrysos*, gold.

**Clamer's Alloy.**—A general-purpose white bearing or anti-friction metal. Composition : tin, 5% ; copper, 64% ; lead, 30% ; nickel, 1%.

**Clark's Alloy.**—An imitation silver. Composition : copper, 75% ; nickel, 14.5% ; zinc, 7.5% ; tin, 1.5% ; cobalt, 1.5%.

**Cliché Metal.**—An alloy sometimes used for preparing cloth-printing rollers, engraving plates, etc. Composition : tin, 48 parts ; lead, 32.5 parts ; bismuth, 9 parts ; antimony, 10.5 parts.

**Clock-Case Metal.**—A type of brass used for clock bezels and other ornamental purposes. Has a smooth surface and takes lacquer well. Composition : copper, 68% ; zinc, 32%.

**Coarse Solder.**—(See **Plumber's Solder.**)

**Cobalt.**—Metallic element. Chemical symbol, Co ; At. No. 27 ; At. Wt. 59 ; M.P. 1480° C. ; Sp. Grav. 8.6 ; Sp. Ht. 0.107 ; Coef. Exp. 0.0000124 ; Therm. Cond. (Silver = 100) 17.2 Elec. Cond. at 0° C. (Mercury = 1) 9.685.

Chief ores : Cobaltite or Cobalt glance,  $\text{CoAsS}$  ; Smaltite,  $\text{CoAs}_2$ . Also frequently contained in nickel ores.

Cobalt was first recognised as an element by Brandt in 1735. Its name is derived from the German *Kobold*, a goblin or sprite, because the old German miners considered cobalt ores to be useless and, indeed, injurious to other metals.

Cobalt is a hard white metal, similar to nickel in appearance, but having a slight bluish cast. It is malleable, ductile and feebly magnetic, properties which it shares in common with nickel. It oxidises very slowly in moist air, and is acted upon in the ordinary way by the common acids. Cobalt in thin films is said to have the property of absorbing hydrogen. In all its chemical properties, cobalt is very closely related to nickel. In the metallic form, cobalt is a most important constituent of many steels, and its various chemical compounds, particularly the insoluble pigments which it gives rise to, are of considerable importance.

## COBALT BLOOM

**Cobalt Bloom.**—A cobalt-arsenic oxide.

**Cobalt Chrome Steel.**—An alloy steel having a high resistance to pitting and high-temperature deformation. Composition : iron, 80% ; chromium, 13.3% ; cobalt, 3.7% ; carbon, 1.5% ; molybdenum, 0.7% ; silicon, 0.4% ; manganese, 0.4%. It has many applications.

**Cobalt-Chromium Steels.**—At one time employed for the exhaust valves of motor engines, their great hardness preventing scoring. Their mechanical properties, however, fall off with high temperatures, and they have now largely been replaced by the chromium steels. Another important steel with numerous applications.

**Cobalt Steels.**—These were first investigated by Sir Robert Hadfield in 1891. They may contain up to 35% of cobalt. They are characterised by their great magnetic permeability, for which reason they are employed as magnet steels.

**Cobalite.**—An important cobalt-bearing mineral. Chemical symbol, CoAsS.

**Cochrome.**—A cobalt-chromium alloy.

**Coffin Metal.**—A lead-tin alloy used for making metal coffins. Approximate composition : lead, 45 parts ; tin, 40 parts ; copper, 15 parts.

**Coinage Bronze.**—This usually contains : copper, 95% ; tin, 4% ; zinc, 1%. It is hard and slow wearing under ordinary conditions.

**Coinage Copper.**—This usually contains : copper, 95% ; tin, 4% ; zinc, 1%, although these proportions vary from time to time.

**Coinage Metals.**—These comprise copper, silver and gold, and, to a certain extent, nickel. Platinum is also sometimes used for coinage purposes.

These metals (and/or their special alloys) are employed for coinage purposes because they are sufficiently plastic under pressure to be "struck" with dies, they are tough and not easily broken, they do not readily corrode in air or water, and because, if necessary, they can be hardened by admixture with other metals, to meet the hard wear of ordinary coinage.

**Coinage Silver.**—Prior to 1914 this contained : silver, 92.5% ; copper, 7.2% ; lead, 0.2% ; gold, 0.1%.

**"Cold Short."**—(See "Short.")

**Colorado Silver.**—A nickel silver. Composition : copper, 57% ; nickel, 25% ; zinc, 18%.

**Columbium.**—Metallic element. Chemical symbol, Cb ; At. No. 41 ; At. Wt. 93.5 ; M.P. 1950° C.

Occurs in the rare mineral Columbite or Tantalite.

Discovered in 1844 by H. Rose and called by him "Niobium" (from Niobe, the mythological daughter of Tantalus), since

## CONDUCTIVITY BRONZES

the metal is very similar in properties of tantalum. Of more recent date, the metal has been re-named Columbium (from Columbus, the discoverer of America) in view of its chief sources of ore being situated in America. In many chemical and other reference books, however, the name "Niobium" is still perpetuated.

Columbium is still a rare element. It is a steel-grey, hard, difficultly fusible metal which is resistant to acids and resembles tantalum, its related metal, in appearance and properties. It is used in some of the hard metals.

**Columnar Fracture.**—Name used to describe the appearance of the fractured surfaces of some metals, the metal breaking across into rectangular "fingers" or pieces resembling lump starch. Tin shows this type of fracture when heated to near its melting point and then struck sharply with a mallet.

**Common Brass.**—Another name for **Cast Brass** (which see).

**Common Pewter.**—(See **English Pewter**.)

**Common Solder.**—M.P. 220° C. Composition: tin, 50%; lead, 50%. This alloy constitutes the ordinary solder of the workshop.

**Complex Steels.**—(See **Quaternary Steels**.)

**Composition.**—An alloying ingredient for gold used in the jewellery trade. Jeweller's *composition* consists of brass containing 2 parts copper to 1 of zinc. Zinc and copper in gold harden the metal.

**Composite Iron and Steel.**—(See **Steel-faced Iron**.)

**Conchoidal Fracture.**—Term referring to the characteristic appearance of the broken surfaces of certain varieties of metals, the metal fracturing with a convex or concave surface having shell-like markings. Certain types of hard steels possess this type of fracture. It denotes hardness and brittleness in a metal. (From the Latin *concha*, a shell.)

**Conductivity.**—The power of metals and alloys of transmitting heat and electricity. Hence the terms, "Thermal Conductivity," "Electrical Conductivity." The electrical conductivity of a metal is practically equal to its thermal or heat conductivity, and in both these instances the presence of even a very small amount of impurity in the metal will diminish its conductivity. The electrical conductivity of a metal is much decreased by rise in temperature. Of all metals, silver has the highest thermal and electrical conductivities.

**Conductivity Bronzes.**—Copper alloys containing elements such as tin, silicon and aluminium. Although they have a lesser conductivity than pure copper, they are characterised by great strength and are therefore used instead of pure copper for some purposes for which a maximum copper conductivity is not a paramount necessity.

## CONSTANTAN

**Constantan.**—An electrical high-resistance alloy used for winding resistance coils, etc. Composition : nickel, 40% ; copper, 60%. Also used as a thermo-couple alloy.

**Cooperite.**—A nickel-zirconium alloy somewhat similar to stellite, but not containing tungsten. It is somewhat cheaper than Stellite (which see).

**Cooper's Gold.**—An imitation gold containing platinum. Is never used now, but was employed fairly extensively in the days of relatively inexpensive platinum. Composition : copper, 12 parts ; platinum, 3 parts. The alloy makes an excellent imitation gold.

**Cooper's Mirror Metal.**—An untarnishable metal for mirrors. Takes a very high polish. Composition : platinum, 9.49% ; copper, 57.85% ; zinc, 3.51% ; tin, 27.49% ; arsenic, 1.66%.

**Cooper's Pen Metal.**—A copper-silver-platinum alloy, said to be suitable for pen-nib tipping. Composition : copper, 13 parts ; platinum, 50 parts ; silver, 36 parts.

**Copper.**—Metallic element. Chemical symbol, Cu (from the Latin *cuprum*, a contraction of *Cyprium aes*, "Cyprian brass," the metal having been found in the island of Cyprus by the Romans). At. No. 29 ; At. Wt. 63.5 ; M.P. 1981° C. ; B.P. 2310° C. ; Sp. Grav. 8.82 ; Sp. Ht. 0.0933 ; Coef. Exp. 0.00001678 ; Therm. Cond. (Silver = 100) 73.6 ; Elec. Cond. (Silver = 100) 93.

Chief ores : Copper pyrites,  $\text{CuFeS}_2$ , Ruby ore,  $\text{Cu}_2\text{O}$ , Malachite,  $\text{CuCO}_3\cdot\text{Cu}(\text{OH})_2$ . Also occurs in metallic state.

Copper is one of the oldest known of metals, its use dating from prehistoric times. In alchemical terms, the metal was symbolised by the planet Venus.

It is a lustrous red-brown metal. It is extremely tough and can be hammered out into a thin leaf. It is very ductile, also. When heated to near its melting point, the metal becomes so brittle that it can be powdered. Molten copper is dark sea-green in colour. The vapour of boiling copper is also green. Copper is fairly resistant to atmospheric corrosion and oxidation. Owing to the fact that, next to silver, it is the most electrically conductive of all metals, it is used enormously in the world's electrical industries. Copper for electrical purposes must be almost perfectly pure, since small traces of impurities seriously interfere with its conductivity. As a casting metal, as an ingredient of brass and many other non-ferrous alloys, copper is much used. Molten copper expands on solidifying.

Next to iron, copper is, perhaps, the most generally useful of all metals.

**Copper Amalgam.**—Many types of copper amalgam have been used from time to time. One containing 3 parts copper to 7

parts mercury is plastic, but hardens within a day or two. It has the property of softening and acquiring the consistency of clay by kneading and pounding. Other copper amalgams have been used for filling teeth, sealing vacuum tubes, bottles, etc.

Copper amalgam readily crystallises. It can be rolled and hammered.

**Copper-Chromium Alloys.**—These have chromium contents ranging from 0.5% to 1%. They are sometimes used for the manufacture of welding electrodes on account of their hardness and good electrical conductivity. They sometimes contain traces of other metals, such as silver, beryllium zirconium, cadmium and zinc, and are marketed under various trade names.

**Copper-Cobalt-Beryllium Alloys.**—A new type of copper alloy which has been put forward for its strength at elevated temperatures.

**Copper-Iron-Phosphorus Alloys.**—Typical composition: copper, 97.5%; iron, 2%; phosphorus, 0.5%. A new introduction. They may be heat-treated to give high-conductivity values with great mechanical strength.

**Copper-Lead Alloys.**—This is a copper-tin-lead alloy which has been introduced from America as a bearing metal. Sometimes referred to as "Leaded Bronze" or "Plastic Bronze." Typical compositions are:

- (a) copper, 78%; tin, 7%; lead, 15%;
- (b) copper, 70%; tin, 5%; lead, 25%.

In some instances, the lead percentage in these alloys may be as high as 45%. Usually, copper-lead alloys are employed as a thin layer on a steel shell or base.

**Copper-Nickel-Silicon Alloys.**—These have been employed for locomotive firebox service, a typical alloy of this class containing: copper, 97.5%; nickel, 2%; silicon, 0.5%. Such alloys have been found to be rather brittle, and in some quarters are not favoured.

**Copper Pyrites.**—(See Pyrites.)

**Copper Precipitate.**—Also known as "Cement Copper." More or less impure copper which has been precipitated from copper-bearing solutions. It frequently contains iron and arsenic. It is produced extensively at some refineries.

**Copper Steel.**—A variety of steel introduced in 1899 by A. L. Colby. Copper steels contain, on an average, about 1% of copper. They are fairly hard, and have a better mechanical strength than ordinary mild steel. Moreover, they are more resistant to certain types of chemicals. Copper steel is having an increasing use in this country for the manufacture of such articles as steel sheets, smoke-boxes and ashpan plates of

## CORNISH BRONZE

locomotives. Steel railway sleepers have also been made of copper steel both in America and in Germany.

**Cornish Bronze.**—A type of bronze alloy used as an anti-friction bearing metal. Composition : copper, 77.83% ; tin, 9.60% ; lead, 12.40%, plus a trace of iron.

**Corronium.**—An alloy sometimes used as a bearing metal for heavy loads. It has a high resistance to abrasion and a low coefficient of friction.

Composition : copper, 80% ; zinc, 15% ; tin, 5%. Tensile strength, 22 tons per square inch. Brinell hardness, 85-90. The alloy is really a tin brass.

**Corrosiron.**—A silicon steel containing about 14% of silicon. Is highly acid-resistant.

**Coslettised Iron.**—Iron which has been treated by a rust-proofing process originally devised by Thomas Watts Coslett, an English chemist, in 1907, but later developed and commercialised in America. The process consists in immersing the cleaned iron article in a bath containing a dilute solution of iron phosphate in dilute phosphoric acid, the bath being heated to near its boiling point. In this way, an extremely thin coating of grey iron phosphate is formed on the surface of the iron article. This coating is very hard and tenacious, and it very satisfactorily protects the underlying metal from the ravages of rust and corrosion. The process is one which at the present day is much used in the bicycle and allied trades. (See **Bonderising**.)

**Cothias Metal.**—This constitutes a base alloy which is used as a hardener in a series of zinc alloys. Its composition is : copper, 66.70 parts ; tin, 33.30 parts.

A typical casting alloy containing Cothias metal or alloy is : zinc, 85.6% ; aluminium, 0.4% ; tin, 7.33% ; Cothias metal, 6.67%.

**Covellite.**—One of the sulphide ores of copper. Chemical symbol, CuS. 66.4% Cu.

**Craig Gold.**—An imitation gold. In reality, a brass containing nickel. Composition : copper, 80% ; zinc, 10% ; nickel, 10%.

**Crankcase Alloys.**—These are aluminium alloys of the average composition : aluminium, 91% ; copper, 8% ; iron, 1%. The copper and the iron act as hardening agents. Such alloys are much used in automobile engineering.

**Creep.**—A metallurgical term used to express the gradual and continuous change in the deformation or deflection of a stressed member.

**Crococite.**—A chrome ore. Chemical symbol,  $PbCrO_4$ .

**Cronite.**—A nickel-chromium-iron alloy. Has an expansion coefficient of 13 millionths per degree Centigrade. Is also resistant to corrosion.

**Crucible Steel.**—Crucible steel was at one time made entirely by melting blister steel, made by packing wrought iron in charcoal and heating to a bright red heat and so causing it to absorb carbon. Most of the Crucible Steel is now made by melting wrought iron or open hearth steel in graphite crucibles with the addition of alloying materials desired.

Steel which has been manufactured by the "crucible process," in which the steel is smelted in crucibles placed in a coke-fired furnace of special design. Crucible steels are of very high grade. Nevertheless, the process is gradually being replaced by the electric process in which the most complex alloy steels can be made with the utmost precision.

**"Crude Antimony."**—A commercial term. It implies antimony sulphide, NOT the metal.

**Cryolite.**—A mineral of importance as a constituent of the electrolytic bath in aluminium production. Chemical formula,  $\text{Na}_3\text{AlF}_6$ .

**Crystalline Fracture.**—A type of metal fracture characterised by the crystalline appearance of the broken surfaces. Typical examples of this type of fracture are given by the metals bismuth, zinc and antimony. Metals having crystalline fractures are devoid of tensile strength.

**Cuprite.**—One of the copper minerals found in the oxide ores. Chemical symbol,  $\text{Cu}_2\text{O}$ . 88.8% Cu.

**Cupromanganese.**—(See **Manganese Copper.**)

**Cupro-nickel.**—An alloy in which copper predominates. Cupro-nickel with 20% to 30% nickel has good strength and ductility and is resistant to corrosion. Cupro-nickel alloys exist in great variety, and some also contain zinc, lead, iron, manganese or tin.

**Cutanik.**—One of the commercial brands of cemented or sintered carbides. (See **Tungsten Carbides.**)

## D

**Damascus Bronze.**—An anti-friction bearing metal of fine grain. Composition: copper, 76.41%; tin, 10.60%; lead, 12.52%.

**Dandelion Metal.**—An anti-friction bearing metal. Composition: tin, 10%; lead, 72%; antimony, 18%.

**Darcey's Metal.**—A fusible alloy. Composition: bismuth, 70 parts; lead, 20 parts; tin, 40 parts. Softens at 100° C. and may be kneaded between the protected fingers.

## DEADENED MERCURY

**Deadened Mercury.**—When metallic mercury is ground up with sugar, chalk or lard, it eventually breaks up into a fine grey powder, consisting of extremely small globules of the metal. Such preparations, which find a use in medicine, are often known as "deadened" mercury.

**Dechenite.**—Lead zinc vanadate.

**Decipium.**—At one time considered to be a new metallic element. It was shown to consist mainly of samarium.

**Delalot's Alloy.**—An imitation silver alloy. Composition: copper, 80% ; zinc, 18% ; manganese, 2%. Sometimes 1% of calcium phosphate is added to the alloy mixture.

**Delta Iron.**—Between its freezing or solidifying point and 1404° C. iron is known as Delta Iron. (See **Beta**, **Gamma** and **Alpha**.)

**Delta Metal.**—Trade name of a series of engineering alloys manufactured by the Delta Metal Company Ltd., "Delta" being their Registered Trade Mark. There is a great variety of Delta metals, including copper HC quality, and Delta anti-friction metal No. 9. The founder of the firm was the late Mr. Alexander Dick, a prominent metallurgist, who in 1883 commenced to market his products under the Trade Name "Delta."

Delta metals are individually distinguished by numbers and descriptive words such as Delta Bronze No. 1, Delta Silver Bronze No. 2, Delta Bronze No. 4C, Delta White Anti-friction Metal No. 9, Brass Delta Brand, Delta Zinc, and so on. Other Trade Names of the Company are "Dixtrudo" Brass, "Dix-tambo" Yellow Metal for stampings and forging, whilst "Deltoid" is another of the Company's registered trade marks relating to special metals and alloys.

**Density.**—This is usually taken to mean the *Specific Gravity* of a metal (which see).

**Dental Amalgams.**—Dental amalgams and alloys vary enormously in composition and many of them are more or less secret in nature.

Amalgams of tin, mercury and cadmium have long been used in dentistry. These amalgams become plastic on kneading, and set again without contraction. A copper amalgam is sometimes used in dentistry.

An amalgam of silver, tin gold and mercury is at times used as a metallic "filling" for teeth. Other dental amalgams contain platinum and other rare metals combined with mercury.

**Desilverised Lead.**—Lead from which all the natively-occurring silver has been extracted.

**Dewrance's Metal.**—A white bearing metal for locomotive purposes. Composition: tin, 33.3 parts ; copper, 22.2 parts ; antimony, 44.4 parts.

**Diamond Bronze.**—An aluminium-copper alloy which is very hard but brittle. Sp. Grav. 7.3. Composition : copper, 88% ; aluminium, 10% ; silicon, 2%.

**Diana.**—An alchemical name for silver.

**Diaphragm Steel.**—Name given to the silicon steels employed in the making of telephone diaphragms. It contains from 3% to 4% of silicon.

**Die Steel.**—A carbon steel containing from 0.40% to 0.60% of carbon and sometimes tungsten (17% to 19%), chromium (3% to 4.25%) and up to 1.2% vanadium. It is tough, will resist great pressure and is very easily welded. Used for making stamping and pressing dies, plane-irons, etc. There are many alloy die steels.

**Dilver.**—A nickel-iron alloy containing between 42% and 50% of nickel. Has an expansion coefficient similar to that of glass and is used for the "seal wires" of electric lamps, radio valves, etc., since it provides a perfectly gas-tight joint with the glass. Replaces metallic platinum which was formerly used for this purpose. Is often used in the copper-coated condition, which provides a still stronger union between glass and metal.

"Disease" of Tin. (See Grey Tin.)

**Dolomite.**—One of the minerals producing magnesium. Chemical symbol,  $MgCO_3, CaCO_3$ .

**Domestic Aluminium.**—The "aluminium" out of which pans, dishes and other domestic articles are manufactured is often an alloy containing 97% of aluminium and 3% of copper, the copper acting as a hardening agent.

**Double Shear Steel.** (See Shear Steel.)

**Dowmetal.**—A series of magnesium alloys all containing over 85% of magnesium. The chief characteristic is its extreme lightness, the specific gravity being approx. 1.80. The compositions, of course, vary according to application and the aluminium content may range from 2.5 to 12%, manganese from 0.1 to 1.5%, while some of the alloys have zinc varying from 0.5 to 3%.

**Dry Copper.**—Name applied to copper at one of the final stages of its smelting process. It then contains a little copper oxide as an impurity, which latter is removed by stirring it with wooden poles.

Copper which has remained in contact with the air in a molten condition for an undue length of time. In the molten state it becomes partly oxidised, and the oxide—cuprous oxide,  $Cu_2O$ —dissolves to some extent in the metal, lowering its melting-point from 1083° C. to 1063° C. Copper in this condition becomes very brittle on solidification and it readily fractures. It is termed "dry."

## DUCTILITY

**Ductility.**—The degree of which a metal is capable of being lengthened by the application of a tensile stress or drawing-out force. The readiness with which a metal may be drawn-out depends upon its softness, but the thinness to which it may be so drawn is dependent upon its tensile strength.

The following well-known metals are arranged in order of decreasing ductility : gold, silver, platinum, iron, nickel, copper, zinc, tin, lead.

(From the Latin *ducere*, to lead.)

**Duppler's Metal.**—A silver-zinc alloy. Formerly used for making instrument mirrors. Composition : silver, 80% ; zinc, 20%.

**Durak.** (See **Mazak.**)

**Duralumin.**—One of the most important of the light aluminium alloys. It possesses the remarkable property of slowly increasing in tensile strength in the course of four or five days from 18 to 26 tons per square inch after it has been heated for half an hour to 500° C., and then quenched in water.

The average composition of duralumin is : aluminium, 95% ; copper, 4% ; magnesium, 0.5% ; manganese, 0.5%.

The alloy, on account of its strength, is much used for aircraft work.

(From the French *dur*, hard.)

(See also **Aldural.**)

**Durana Metal.**—A strong brass-like alloy which can be worked at red-heat. Composition : copper, 64.78% ; zinc, 29.50% ; iron, 1.71% ; aluminium, 1.70% ; tin, 2.22%.

**Durehete.**—A steel containing molybdenum, which does not become brittle at high temperatures.

**Durex.**—A graphited bearing metal. It is similar to **Genelite** (which see).

**Duriron.**—A type of silicon steel containing from 14 to 14.5% of silicon and from 0.2 to 0.6% of carbon, together with very small amounts of phosphorus and manganese. Its tensile strength is only three-quarters that of cast iron, but it has a very high resistance to acids, for which reason it is employed for making into acid containers and similar articles.

**Duronze.**—A high silicon bronze alloy made by the Bridgport Brass Co., Ltd. It is made in four grades. Lower melting point than copper and weight less.

**Dutch Gold.**—(See **Dutch Metal.**)

**Dutch Metal.**—One of the brasses. Composition : copper, 80% ; zinc, 20%. It has a golden-yellow colour and is much used for cheap jewellery. Can be made into thin sheets and foil.

**Dwi-Manganese.**—This is the name given by the chemist Mendeléeff for the metal Rhenium, the discovery of which he predicted.

“Dwi” is a Sanskrit numeral, meaning “the second after,” and, in this connection, it refers to the position of rhenium in Mendeléeff’s Periodic Table of Elements.

**Dydimium.**—A “rare earth” mineral found in monazite. (See **Mischmetal.**)

**Dyscrasite.**—A mineral containing silver. Chemical symbol,  $\text{Ag}_3\text{Sb}$ .

**Dysprosium.**—Metallic element. Chemical symbol, Dy ; At. No. 66 ; At. Wt. 162.5.

A rare metal discovered in 1886 by Lecoq de Boisbaudran in certain rare earth minerals, and by him given the name “dysprosium” from the Greek word *dysprositos*, “difficult of access,” in allusion to the difficulty of extracting the metal and its compounds in the pure state. The metal has a light greyish colour, but it is, of course, a mere chemical rarity.

## E

“**E**” **Alloy.**—An English aluminium alloy. Contains : copper, 2.5% ; zinc, 20% ; magnesium, 0.5% ; manganese, 0.5%—remainder aluminium. Tensile strength, 80,000 lb. per square inch.

**Earlumin.**—A Spanish aluminium alloy similar to duralumin.

**Eka-Aluminium.**—A name used by the chemist, D. I. Mendeléeff, to denote the metal Gallium, whose properties he predicted some years before its discovery.

The word “eka” is a Sanskrit numeral. It means “the first after,” referring to the place of gallium in Mendeléeff’s Periodic Table of Elements.

**Eka-Boron.**—Likewise, this was Mendeléeff’s “pre-discovery” name for the metal Scandium, whose discovery he predicted.

**Eka-Silicon.**—Mendeléeff’s name for the metal Germanium, the discovery of which he predicted.

**Elasticity.**—The property of metals (and other bodies) in virtue of which force is required to change their bulk or shape, and by means of which they recover their original shape when the force is removed from them.

If a metal recovered its shape perfectly after an applied force had been removed from it, it would be said to be perfectly elastic.

**Electrical Conductivity.**—(See **Conductivity.**)

**Electric Amalgam.**—Name given to a class of amalgams which are employed in frictional electric machines for assisting the conduction of the generated charges. There are several different varieties of electric amalgam, although they are usually

## ELECTRICIAN'S SOLDER

tin or zinc amalgams. (See **Singer's Amalgam**, **Kienmayer's Amalgam**, **Böttger's Amalgam**.)

**Electrician's Solder**.—A special solder for electrical fittings, etc. Contains : tin, 94.5% ; lead, 5.5%.

**Electric Steels**.—Steels which have been made in the electric furnace. Such steels are now being manufactured in increasing quantities.

**Electric Welding**.—Term describing various welding operations in which the ends of the metals to be united are placed in contact and a powerful electric current is passed through them. The high resistance of the metal junction (owing to poor contact) creates intense heat which welds the metals together.

There are many modern modifications of this fundamental principle.

**Electrolytic Copper**.—This is copper of the highest commercial purity which has been refined by a process of electrolysis. It contains about 99.86% of copper. It is essential to employ copper of this purity for most electrical purposes, for the presence of any impurities often considerably reduces the electrical conductivity of the metal.

**Elektron**.—The trade mark "Elektron" relates to a wide range of magnesium alloys. These are the lightest commercial alloys available, being bulk for bulk two-thirds the weight of dur-alumin and one-quarter the weight of steel, the respective specific gravities being 1.82, 2.81 and 7.8. The corresponding strength/density ratios are : Elektron 11.1, Duralumin 9.3, Heat-treated nickel chrome Steel 7.0, and Mild Steel 3.6. Elektron castings have mechanical properties equal to those of the normal aluminium alloys and are approx. 40% lighter. The machining quality of Elektron is excellent and the possible cutting speed is limited only by the machine-tool capacity. Elektron may be welded as easily as aluminium or steel. Normal atmospheric conditions have little effect upon Elektron and for sea-water corrosion a special surface treatment is available. It has, of course, an extremely low melting-point.

**Electrum**.—A formerly popular ornamental metal, similar in appearance to German or nickel silver. Composition : copper, 51.5% ; zinc, 22.5% ; nickel, 26%.

**Elinvar**.—An alloy containing 36% of nickel and approximately 12% of chromium, and sometimes small quantities of manganese, tungsten and carbon, in which case the chromium content is less. The great advantage of this alloy is that at ordinary temperatures it has a practically invariable elastic modulus, coupled with a very low thermal expansivity. It therefore finds great use in the manufacture of certain grades of scientific instruments as well as for high-grade pendulums of accurate clocks.

**Elongation.**—Term used in metallurgy to denote the amount of extension which occurs in a metal before it fractures when such a metal is subjected to stretching strains. The elongation of a metal is usually expressed as a percentage of the original length of the metal.

**Emerald Brass.**—A hard brass alloy of a rich golden colour. Gives a good colour when lacquered and is much used for ornamental purposes. Composition: copper, 50% ; zinc, 49% ; aluminium, 0.5-1%.

**Emmel Iron.**—This is made by pouring specially melted and controlled mixtures into ordinary sand moulds. A typical example contains 2.6% of carbon, 0.75% of combined carbon, 2.3% of silicon, 0.15% of phosphorus, 1% of manganese, 0.11% of sulphur. Tensile strength is about 22 tons per square inch.

**Enargite.**—One of the sulphide ores of copper. Chemical symbol,  $Cu_3AsS_4$ . 48.3% Cu.

**Enduron.**—Heat-resisting high-chromium iron. Tensile, 35 tons per square inch. Heat and scale-resisting up to 1000° C. Resists corrosion. Unsuitable to withstand repeated impact.

**English Metal.**—A variety of Britannia metal containing the following ingredients: tin, 87 parts ; copper, 2 parts ; brass, 1 part ; nickel, 2 parts ; bismuth, 0.5 part ; antimony, 6 parts ; tungsten, 1.5 parts.

**English Pewter.**—Also known as Common Pewter. Composition: tin, 80% ; lead, 20%. M.P. 186° C. (367° F.).

**English Standard Gold.**—(See Standard Gold.)

**English Standard Silver.**—(See Standard Silver.)

**Erbium.**—Metallic element. Chemical symbol, Er ; At. No. 68 ; At. Wt. 167.7.

A rare metal, the oxide of which is found in traces in the mineral gadolinite, found at Ytterby, in Sweden, and from the latter half of which name the metal's title was derived. Originally discovered (in the form of its oxide, "erbia") by Mosander about 1840. Although much work has been done on the subject, in America, it is doubtful whether perfectly pure erbium has ever yet been obtained.

**Erythronium.**—This was the name given in 1801 by Del Rio to the metallic element contained in a lead ore which he had obtained from Mexico. The name was derived from the Greek *erythros*, red, on account of the red salts which were obtained from this ore. Subsequently, "erythronium" was re-named "Vanadium." (See Vanadium.)

**Eudialyte.**—A mineral in which zirconium appears.

**Eureka.**—A nickel-silver resistance alloy. Composition: nickel, 43% ; copper, 57%.

## **EUROPIUM**

**Europium.**—Metallic element. Chemical symbol, Eu ; At. No. 63 ; At. Wt. 152. Discovered in 1901 by E. Demarçay, and given its name in allusion to the continent of Europe.

Despite the fact that it is said to occur to the extent of 0.02% in some varieties of monazite sand, europium is one of the rarest of rare metals, and it has only been prepared in minute quantities.

Although a very rare metal on earth, europium has been discovered by spectroscopic methods in the sun and in some of the brighter stars.

**Eutectic.**—When two different molten metals are mixed a uniform liquid solution is obtained. It begins to freeze at a set temperature depending on the composition of the alloy and continues to freeze until another set temperature is reached, below which it is completely solid. There is thus a definite temperature range of freezing or solidification. The extent of this range varies according to the proportion in which the alloys are present. If we take the case of an alloy of gold and silver we know that the solidifying temperature of pure gold is 1063° C. If, however, we have a liquid solution containing 80% of gold and 40% of silver it begins to solidify or crystallise at approximately 1050° C. and continues to solidify until the temperature has dropped to about 1000° C. Thus, the eutectic point of any alloy depends upon the temperatures at which freezing begins and at which it becomes completely solid.

**Eutectoid.**—The Eutectoid in steel is a mechanical mixture formed at 695° C., having an average carbon content of 0.9% of carbon and consisting of cementite and ferrite in definite proportions. This Eutectoid mixture is known as Pearlite by metallurgists.

**Evans's Metallic Cement.**—Made by dissolving cadmium amalgam (26 cadmium, 74 mercury) in mercury and by pressing out the excess of mercury. Becomes very plastic by kneading.

**Everdur.**—An alloy containing copper, silicon and manganese. Its chief characteristic is its corrosion-resisting properties which equal that of copper. It has the strength of mild steel. It is manufactured with its constituents in varying proportion. A typical wrought alloy contains 96% of copper, 1% of manganese and 3% of silicon. The tensile strength of rods and bars is approx. 50,000 lb. per square inch, whilst hard rods and bars vary between 60,000 and 90,000 lb. per square inch. It is manufactured in the form of strips, tubing, plates and sheets and may be either hot or cold rolled. It is easily welded by any of the various welding processes. Water-heating and storage tanks are frequently manufactured from Everdur.

**Everest Metal.**—A bearing or white-metal alloy of the anti-

friction class. Composition : antimony, 14-16% ; tin, 5-7% ; copper, 0.8-1.2% ; nickel, 0.7-1.5% ; arsenic, 0.3-0.8% ; cadmium 0.7-1.5%—remainder lead. Also known as "Thermit" metal.

**Explosive Antimony.**—A black powder obtained by the rapid cooling of antimony vapour, or, better still, by the electrolysis of a solution of antimony chloride in hydrochloric acid, using a platinum cathode and an antimony anode. Under these latter conditions "explosive" antimony will be deposited on the cathode as a hard black mass. When scratched, this will explode.

The nature of "explosive" antimony is unknown, but it is considered (in at least one of its forms) to comprise a solid solution of antimony trichloride in metallic antimony.

**Extra-Terrestrial Metals.**—Metals which have been derived from sources beyond the earth in the form of meteorites. Gold, iron, nickel, cobalt, tungsten and other metals are frequently contained in meteorites and are, therefore, "extra-terrestrial" metals.

**Extrusion Brass.**—A soft brass for extrusion and other purposes. Composition : copper, 55% ; zinc, 45%.

## F

**Fahlun Brilliant.**—A tin-lead alloy used for making stage jewellery. Composition : tin, 29 parts ; lead, 19 parts.

It is cast into moulds having facets of a diamond shape, and, when viewed from a distance under artificial light, its lustre is such that "brilliants" cast in this metal have the appearance of diamonds.

**Faraday's Gold.**—Name given to a colloidal solution of gold obtained by adding a few drops of a reducing agent, such as formalin, to a very weak solution of gold chloride. It was first studied by Michael Faraday in 1857.

**Fatigue.**—Term used to denote the gradual deterioration in properties of some metals after they have been in use over long periods. Metal fatigue is due to internal changes proceeding within the metal. Such changes are brought about by frequent alterations in the conditions of temperature, stress, vibration, etc., to which a metal may have been subjected.

**Fenton's Metal.**—A white bearing or anti-friction metal, employed specially for axle-boxes of locomotives and wagons. Composition : zinc, 80% ; tin, 14.5% ; copper, 5.5%.

**Ferberite.**—One of the minerals of tungsten. Chemical symbol,  $\text{FeO} \cdot \text{WO}_3$  or  $2\text{FeWO}_4 \cdot \text{FeO}$ .

## FERGUSONITE

**Fergusonite.**—A tantalum ore, comprising natural combinations of tantalum, columbium, iron, calcium, yttrium, and cerium.

**Ferrite.**—When a 0.5% carbon steel is cooled practically pure iron is precipitated from 780° C. to 695° C. The iron precipitated in this way is known as Ferrite, a term which distinguishes it from the iron of the Eutectoid.

**Ferrocarr.**—Dust iron suitably amalgamated with some binding agent and used in the manufacture of wireless coils and inductances. It was the invention of Hans Vogt. (See also **Permalloy**, **Polydoroff**, and **Atmalloy**.)

**Ferro-Cerium.**—An alloy of iron and cerium used for making lighter flints.

**Ferrochrome.**—Produced by the direct reduction of chromite with carbon without the use of fluxes.

**Ferrolite Process.**—The Ferrolite metal cleaning process is an American invention (U.S. Patent 1,995,766) and employs A.C. current for pickling in sulphuric acid solution of varying acidity (5-10%). About one-tenth by volume of the total bath acidity is composed of gluconic acid or a mixture of organic sugar acids. Graphite electrodes are employed and the steel is contained in acid-resisting baskets and lowered between the two electrodes without actually touching either of them. Sixty-cycle A.C. current is caused to pass through the solution, and the steel is rapidly pickled. The process is excellent for deep recesses, which quickly have their scale detached, but under present conditions it may be difficult to obtain the requisite ingredients of the bath.

The gluconic acid dissolves the ferrous oxide and regeneratively catalyses the inorganic acid ions, in this instance the sulphate ion. The sulphuric acid carries the current and attacks the iron oxides.

**Ferro-Manganese.**—A white granular iron containing 25% to 85% Mn with the C increasing to the Mn. The standard alloy is 80% Mn. (See **Spiegeleisen**.)

An alloy of iron and manganese containing from 78% to 82% of manganese and from 4% to 6% of carbon. A hard, glassy material, used in the manufacture of manganese steels. Manganese alloys containing less than 50% manganese are generally known as spiegeleisen.

**Ferro-Molybdenum.**—The form in which molybdenum is added to cast iron and also to steel. The usual percentage of molybdenum in the ferro-alloy is between 50% and 65%. The carbon content is usually not more than 2%.

**Ferro-Nickel.**—An iron-nickel alloy, containing from 25% to 75% of nickel, used in the manufacture of nickel steels.

**Ferro-Tungsten.**—Alloy of tungsten produced by a process in which purified tungsten concentrate is mixed with coal or

## FIBROUS FRACTURE

other form of carbon and fired. A small amount of siliceous flux is sometimes used.

**Ferro-Vanadium.**—A vanadium alloy containing 35% to 45% vanadium and sometimes as much as 80% of vanadium. It is produced by reacting upon  $V_2O_5$  with aluminium in the presence of metallic iron and fluxes by the aluminothermic.

**Ferro-Zirconium.**—A zirconium ore.

**Ferrous Alloying Elements.**—These are the various elements which are employed for alloying with steel in the preparation of the now very numerous "alloy steels" or "special steels."

They are :

Nickel	Cobalt	Copper
Manganese	Chromium	Titanium
Vanadium	Tungsten	Aluminium
Silicon	Molybdenum	Uranium
Zirconium	Beryllium	

**Ferrous Alloys.**—Alloys containing iron or steel. (From the Latin *ferrum*, iron.)

**Ferrule Brass.**—A variety of brass used for casting plumbers' bobs. It contains lead and is heavier than ordinary brass. Composition : copper, 54% ; zinc, 40% ; lead, 5% ; aluminium, 1%. Sometimes called "Bob Brass."

**Ferry Metal.**—A high-resistance copper-nickel alloy containing approximately 45% of nickel. Used for making resistance wire.

**Fescolising.**—A proprietary process of plating invented by Fescol Ltd. In this a heavy deposit of nickel, say above 0.02 in., is employed to build up worn or undersized metallic articles. It can be used for both large and small parts, and is applicable to both carbon and alloy steels, case-hardening steels, cast iron, and, if desired, to stainless steel and monel metal. It is also applicable to malleable iron, the brasses and bronzes. Mostly, however, it is used for steel. The parts to be fescolised are first cleaned, then dipped in a tank of molten wax of low melting point, which gives the part a wax coating. The wax is carefully cleaned off from the parts to be built up and the exposed parts cleaned in an electrolytic cleaner. After rinsing, and while still moist, the parts are immersed in a plating tank at 80 deg. F. Up to 2 tons can be taken by these tanks. The time is governed by the thickness of the coating. Sometimes two or three days may be required. Deposits range from a few thousandths up to  $\frac{1}{2}$  in. After the plating operation, the wax is removed by immersion, and the recreated surfaces machined or ground to dimensions.

**Fibrous Fracture.**—Term referring to the appearance of some fractured metal surfaces, notably wrought iron. Metals showing fibrous fractures are tough and enduring.

## FILE ALLOYS

**File Alloys.**—Many copper-tin alloys are employed for the manufacture of files, such files (to distinguish them from steel files) being designated "composition files." A typical file alloy has the composition: copper, 64.4%; tin, 18%; zinc, 10%; lead, 7.6%.

**Fine Silver.**—Jewellery trade-name for pure silver. 1,000 parts of fine silver actually contains 1,000 parts of metallic silver.

**Fine Solder.**—M.P. 181° C. Composition: tin, 64%; lead, 36%. This constitutes the lowest melting of the tin solders.

**Fine Zinc.**—Name given to the highest grades of commercial spelter or zinc.

**Flints, Lighter.**—(See Pyrophoric Alloys.)

**Florentium.**—(See Illinium.)

**Floured Mercury.**—Generic term applied to mercury when it is in a state of fine division, as, for instance, when it forms a grey powder when ground up with chalk. In all such instances the metallic mercury is reduced to the condition of very fine globules which will not unite together.

**Flowers of Zinc.**—An extremely fine metallic powder occurring as the flue dust of zinc furnaces. It is chiefly composed of metallic zinc.

**Fontainemoreau's Bronze.**—Name given to a number of now old-fashioned alloys containing zinc, copper, cast iron and lead. These so-called bronzes were cast in iron moulds and were used for statuette work, etc. They are practically obsolete.

**Fracture.**—In metallurgy, this is the term used to denote the appearance of metals when freshly broken.

Metal fractures may be: crystalline, granular, fibrous, silky, conchoidal or columnar.

The fracture of a metal varies to some extent with the purity of the metal, its temperature and the manner in which the rupture has been produced.

**Franklinite.**—A mineral, chemical symbol



containing 39% to 47% Fe, 10-19% Mn, and about 22% Zn.

It is an important source of ZnmO, but not of metallic zinc.

**French Gold.**—(See Oreide.)

**French Pewter.**—Very similar to English or common pewter. Composition: tin, 82%; lead, 18%.

**Frosted Silver.**—A characteristic matt appearance on silver produced by heating the silver article for a short time in air, which process converts surface layer of copper (with which commercial silver is alloyed) into copper oxide, the latter being subsequently dissolved away in a bath of sulphuric acid.

**Fulminating Gold.**—This is not a metal, but is a yellow-brown powder of more or less unknown composition which is obtained

by adding ammonia to a solution of gold chloride. It is extremely explosive and detonates with violence when rubbed or gently warmed.

**Fulminating Mercury.**—Another name for mercury fulminate, the well-known detonating agent which is employed in the percussion caps of cartridges, shells, etc. It is obtained by the action of nitric acid and alcohol on mercury. It is a powerful detonating substance and is extremely dangerous to handle.

**Fulminating Silver.**—Not a metallic substance, but a black powder (believed to consist of silver nitride,  $\text{Ag}_3\text{N}$ ) which is obtained when a solution of silver oxide in ammonia is allowed to stand for some time. It is an extremely explosive material, and sometimes detonates even in the wet state.

**Fusible Alloys.**—Name given to a large group of alloys containing lead, tin, bismuth, antimony and sometimes other metals. Such alloys melt at an unusually low temperature, some of them melting when immersed in warm water. They are based on the property of certain metals to melt at a lower temperature when alloyed with other metals than they do in the unalloyed state.

Fusible alloys are difficult to obtain in the perfectly homogeneous condition, since, when melted, the heavier components of the alloy tend to sink down to the bottom of the mass of metal.

The addition of mercury to any fusible alloy lowers its melting point still further, and may result in the alloy attaining a permanently pasty condition.

In this Dictionary, the fusible metals are entered under their individual names, as, for example, *Wood's Metal*.

**Fusion Welding.**—A generic term which can be used to describe any type of metal welding, such as oxy-hydrogen, oxy-acetylene welding, etc.

## G

**Gadolinium.**—Metallic element. Chemical symbol, Gd; At. No. 64; At. Wt. 157.

A rare metal discovered in 1886 by Lecoq de Boisbaudran in the rare mineral gadolinite, which latter was first discovered in 1794 by J. Gadolin, a Finnish chemist (1760–1852), and subsequently named after him.

Although gadolinium is, perhaps, the "commonest" of the rare metals, it is sufficiently scarce to have, as yet, only been prepared in small quantities. It is a greyish metal, allied in properties to europium and terbium.

## GALENA

**Galena.**—A sulphide lead ore. Chemical symbol, PbS. 806% Pb. This mineral is the world's principal source of lead. It is associated with other sulphides and usually carries traces of silver.

**Gallium.**—Metallic element. Chemical symbol, Ga ; At. No. 31 ; At. Wt. 70 ; M.P. 30° C. ; Sp. Grav. 5.9. Occurs in minute quantities in a number of zinc ores, an ore containing as little as 0.002% of gallium being considered to be rich in the metal.

Gallium was discovered in 1875 by Lecoq de Boisbaudran, a French chemist, who derived its title from *Gallia*, the Latin name for France.

Gallium is related to aluminium in properties. It is a silvery-grey metal having a greenish-blue reflection. Its extremely low melting point (30° C.) constitutes its main characteristic, and molten gallium remains liquid at temperatures considerably below that of its melting point unless touched with a piece of solid gallium, when it instantly congeals. In consequence of its low melting point, attempts have been made to substitute metallic gallium for mercury in high-temperature thermometers. Such endeavours, however, have not been successful, for, unlike mercury, molten gallium "wets" glass and clings to it like water, thereby preventing a definite temperature-reading from being obtained. Gallium, therefore, still remains a mere chemical curiosity, although, doubtless, it possesses latent and yet undiscovered uses.

**Galvanised Iron.**—Iron which has been covered with a protective layer of zinc to prevent it from rusting. In the galvanising process, the sheet iron is cleaned with acid or by means of a fine sand-blast and afterwards dipped in molten zinc. In another process, the zinc coating is deposited electrolytically.

In the presence of water a galvanic action is set up between the zinc and the underlying iron, whereby the zinc very slowly dissolves and no rusting of the iron occurs so long as any of the surface zinc remains. The term "galvanised" is, of course, derived from Luigi Galvani, the electrician of Bologna (1737-98). (See **Sacrificial Metal**.)

**Gamma Iron.**—Between 1404° C. and 900° C. iron is known as Gamma Iron. (See **Alpha, Beta and Delta**.)

**Garnallite.**—One of the minerals producing magnesium. Chemical symbol,  $MgCl_2 \cdot KCl \cdot 6H_2O$ .

**Garnierite.**—A hydrosilicate of Ni and Mg. It is a nickel mineral. The production of nickel from garnierite is somewhat simpler than its production from other ores since it does not involve a separation of copper and nickel. An approximate analysis of the New Caledonia ore is Ni, 5% to 6% ;  $Fe_2O_3$ , 14 ; MgO, 15 ;  $SiO_2$ , 48 ; combined with  $H_2O$ , 10.

## GILDING METAL

**Gearing Bronze.**—A class of bronzes used for gearing wheels. They contain: copper, from 88% to 91%; tin, from 12% to 9%, in addition to a small amount of phosphorus which acts as a purifier.

**Gecalloy.**—A nickel-iron alloy for cable-loading work developed by the General Electric Company.

**Gedge's Alloy.**—An alloy similar to sterro metal and formerly used for ship sheathing. Composition: copper, 60 parts; zinc, 38 parts; iron, 1.5 parts.

**Genelite.**—A "synthetic" bearing metal material consisting of graphite impregnated with metal. Developed in America by the General Electric Company. It has a low tensile strength (3½ tons per square inch), but the material is very porous and will absorb about 3% of its weight of oil which is gradually exuded when the bearing is in use, thus maintaining the latter in a satisfactorily lubricated condition.

**German Alloy.**—An aluminium alloy comprising: copper, 2%; zinc, 12%—remainder aluminium. Much used on the Continent. Brinell hardness, 60–80. Tensile strength, 20,000 lb. per square inch.

**Germanium.**—Metallic element. Chemical symbol, Ge; At. No. 32; At. Wt. 72; M.P. 958° C.; Sp. Grav. 5.47.

Discovered in 1885 by C. Winkler, in argyrodite, a silver ore, which he found to contain about 7% of a new element, subsequently termed by him "Germanium" from *Germania*, the Latin name for his country.

Germanium is a metal which is related to tin on the one hand and to silicon on the other. It is greyish-white, lustrous, and brittle and, in ordinary air, is untarnished.

**German Silver.**—This is identical with **Nickel Silver** (which see).

**Gersdorffite.**—A sulphide mineral containing nickel. Chemical symbol, NiAsS.

**Gersnein's Alloy.**—This makes a soft cement for uniting glass and pottery. In the course of time it becomes hard and can be polished. It is made by grinding 25 to 35 parts of copper powder in a mortar with a little strong sulphuric acid. Then 65 to 70 parts of mercury are added gradually. When all the copper and mercury have amalgamated, the mass is washed with hot water to get rid of the acid.

The material gradually hardens, but it can always be softened by heating it and then pounding it in a mortar. It has from time to time been used by dentists for filling teeth.

**Gilding Metal.**—An alloy of copper and zinc, containing from 80% to 95% of copper. Is used on account of its attractive golden colour in cheap jewellery and for certain decorative applications. Wire made of this alloy has considerable tensile

## GLASS-CEMENTING ALLOY

strength, ranging from 18 tons per square inch (annealed) to 40 tons per square inch (hard drawn).

**Glass-Cementing Alloy.**—Composition : lead, 3 parts ; tin, 2 ; bismuth, 2.5 ; M.P. 100° C.

A fusible alloy, melting at the temperature of boiling water.

**Glass-Silvering Amalgam.**—These amalgams are used for silvering glass globes. They consist of equal parts of lead, tin and bismuth, plus one or two parts of mercury.

**Glucinum.**—The former name for **Beryllium** (which see).

The name glucinum was originally derived from the Greek *glykys*, sweet, in allusion to the sweet taste of solutions of beryllium compounds. To all intents and purposes, however, this name is now quite obsolete, although in some chemical textbooks the name (and with it the chemical symbol, Gl) still persists.

**Glyco Metal.**—An anti-friction metal. Composition : lead, 70% ; antimony, 22% ; tin, 8%.

**Gold.**—Metallic element. Chemical symbol, Au (from the Latin *aurum*) ; At. No. 79 ; At. Wt. 197 ; M.P. 1062° C. ; B.P. 2530° C. ; Sp. Grav. 19.5 ; Sp. Ht. 0.030 ; Coef. Exp. 0.0000147 ; Therm. Cond. (Silver = 100) 76.0 ; Elec. Cond. at 0° C. (Mercury = 1) 72.

Gold is one of the prehistoric metals, having been known from the earliest times. The alchemists called it *sol* (the sun) and represented it by the circle, the symbol of perfection, for, to them, gold was the most perfect of all metals. Gold is usually found in the metallic state. It is widely distributed in Nature. Sea-water contains 3½ grains of gold per ton, and granite, on the average, contains 0.37 parts of gold per million tons. Gold is a yellow metal, being the most malleable and ductile of all metals. Gold sheets as thin as 0.000004 inch have been made. In such thin sheets, gold transmits green light, and the vapour of boiling gold is also green.

Gold is not acted upon by air or oxygen, or by most chemical reagents. Hence it forms one of a group of *Noble* metals, which remain unattacked by most influences. Hot selenic acid is the only single acid which will dissolve gold. The metal is, of course, dissolved by *aqua regia*, a mixture of strong nitric and hydrochloric acids. As a coinage and jewellery metal, gold has been used from very ancient times. It has also constituted a store of value *par excellence*. As an ordinary working metal, however, it is useless, being, in the unalloyed state, too soft. In the form of gold leaf and in various alloyed conditions, the metal, despite its high price, is still used enormously.

**Gold Amalgam.**—Standard "saturated" amalgam is : gold, 2 parts ; mercury, 1 part. This has the consistency of wax.

Gold very readily forms amalgams. A piece of gold rubbed over with mercury is at once penetrated by the latter and becomes exceedingly brittle. Gold leaf suspended in the fumes of warm mercury rapidly becomes amalgamated.

The pasty amalgam containing 1 part gold, 8-9 parts of mercury, forms the basis of the old methods of gilding.

**Gold-Copper.**—An alloy very similar in appearance and composition to **Chrysocalk** (which see). Used for cheap jewellery. Composition: copper, 95 parts; zinc, 7.9 parts; lead, 1.6 parts.

**Goldine.**—An imitation gold. In reality, a brass. Composition; copper, 90%; zinc, 10%.

**Gold Leaf.** (See **Leaf Gold.**)

**Gold Solder.**—Gold solders usually consist of gold alloyed with silver and copper and sometimes, also, a small proportion of zinc. If they melt above red-heat, they are termed "hard" solders. Gold solders are usually made specially to match in gold the different varieties of gold which they are intended to solder. Hence, there are many different types of these solders.

**Gong Metal.**—A sonorous metal for cymbals, gongs, etc., composed of 100 parts of copper and 25 parts of tin.

**Goslarite.**—Sulphate zinc-bearing mineral. Chemical symbol,  $\text{ZnSO}_4 + 7\text{H}_2\text{O}$ . 22.65% Zn.

**Grain Tin.**—Name given to the upper portion of a mass of molten tin at the refinery, which, being the purest, is separately collected.

**Graney Bronze.**—An anti-friction bearing metal. Composition: copper, 75.8%; tin, 9.2%; lead, 15%.

**Granodising.**—A process for preventing corrosion of ferrous metals. In this, the ferrous surfaces, two at a time, are immersed in a hot solution of zinc phosphate and an alternating current of electricity passed with a current density of about 35 amperes per square foot. The film which is developed does not conduct electricity, so that the current gradually falls to near zero as the work is completed. This is again a process which is favoured for small iron parts which have subsequently to be enamelled.

**Granular Fracture.**—Term referring to a type of metal fracture in which the broken metal surfaces have a rough sandstone-like appearance. Cast iron has a granular fracture.

**Granulated Zinc.**—Irregular-shaped fragments of zinc resulting from the pouring of molten zinc into water. Used in chemistry as a source of hydrogen when acted upon by hydrochloric or sulphuric acids.

**Graphalloy.**—Name given to an experimental bearing metal comprising graphite impregnated at high pressure with a metal

## GRAPHITE ALLOY

such as lead. It was claimed that this type of bearing metal could run hot for considerable periods without giving rise to trouble; also that the bearing metal would function without lubricant.

**Graphite Alloy.**—An anti-friction metal for machine bearings. Its appearance is similar to that of graphite. Composition: lead, 68%; antimony, 17%; tin, 15%.

**Graphited Bearing Metals.**—Bearing metals in which graphite has, by one means or another, been incorporated in order to decrease the friction of the bearing. In some of these "composite" metals, the metal is impregnated into the graphite under pressure; in others, a layer of metal is electrolytically deposited upon a layer of graphite, and, this process being repeated, a laminated metal is built up.

**Gravity.**—(See **Specific Gravity.**)

**Green Gold.**—A gold-silver alloy containing from 10% to 25% of silver. Is greenish-yellow in colour.

**Greenockite.**—An important mineral containing cadmium. Chemical symbol, CdS.

**Grey Arsenic.**—Also known as "gamma" arsenic. This is the ordinary variety of arsenic. (See **Arsenic.**)

**Grey Gold.**—A gold-iron alloy containing one-sixth of its weight of iron. It is greyish-yellow in colour.

**Grey Pig Iron.**—(See **Pig Iron.**)

**Grey Tin.**—When tin is cooled to a low temperature, it crumbles into a powder known as "grey tin." Herein lies the cause of the so-called "tin pest" or "tin disease" whereby tin objects, such as organ pipes, sometimes crumble away during a cold winter.

"Grey tin" appears to be a definite variety of tin which is formed slowly at temperatures below 18° C., and it is an extraordinary fact that if a piece of sound "white" tin be placed in contact with a piece of tin suffering from the "disease" or "pest," it will become infected.

**Gunmetal.**—Name given to a group of bronzes. Gunmetal is composed of copper alloyed with from 8% to 12% of tin, the strength of the alloy increasing (and its ductility slightly decreasing) as the percentage of tin increases. Was formerly used for making cannon. Is now employed for instrument work, etc. Technically known as "Soft Bronze."

## H

**Hafnium.**—Metallic element. Chemical symbol, Hf; At. No. 72; At. Wt. 178.6; M.P. 2,220° C.; Sp. Grav. 13.1.

Discovered in 1923 by Coster and von Hevesy in the city of

Copenhagen, after whose Latinised name (*Hafniae*) the element was named.

**Occurrence** : In zirconium ores. In these ores it is nearly always present in amounts up to 1%, whilst in rarer zirconium ores it may exist to the extent of 30%.

Hafnium is a metal similar to zirconium in appearance and properties. It has been used for alloying with the tungsten filaments of electric incandescent lamps in order to increase their strength. It may have future uses as a constituent of alloy steels.

**Hamilton's Metal.**—A form of brass introduced in 1826 by Hamilton and Parker. It usually consists of a 50 : 50 copper-zinc brass. Sometimes used as an "imitation gold."

**Hard Bronze.**—(See **Bell Metal**.)

**Hardenite.**—This name has sometimes been given to a solid solution of carbon in iron, the iron containing 0.89% of carbon.

**Hard Lead.**—Name sometimes given to an alloy consisting of lead, 84 parts; antimony, 16 parts.

**Hardness.**—The resistance of a metal to cutting or abrasion. Frequently, the hardness of a metal is increased by the presence of impurities within the metal, so that a pure metal is often softer than an impure one. Thus, for example, gold is hardened by alloying with it a small quantity of copper.

The softness of metals increases (or their hardness decreases) with increase in temperature. Manganese, cobalt and nickel are the hardest of the common metals, lead constituting the softest of such metals.

The property of hardness depends upon the inner attractions of the molecules of the metal for one another. The hardness of metals is nowadays commonly given in terms of their Diamond Hardness Number, or their **Brinell Number** (which see; also page 166).

There are other hardness tests—The Rockwell, V.D.H., Scleroscope, etc.

**Hard Steel.**—(See **Steel**.)

**Harness Brass.**—(See **Aluminised Yellow Brass**.)

**Harrington Bronze.**—An anti-friction bearing metal. Composition: zinc, 42.67%; copper, 55.73%; tin, 0.97%.

**Harveyised Steel.**—This is steel (generally in the form of steel plates) which has been surface-hardened by heating in contact with charcoal.

**H.C. Copper.**—High Conductivity copper. A very pure form of metallic copper.

**Heat Conductivity.**—(See **Conductivity**.)

**Heat-Treatment.**—The structure and properties of metals and alloys are often very greatly influenced by any heat-treatment which they may receive. Such heat-treatment may embody

## HEAVY PLATINUM METALS

the heating of the metal to a pre-determined temperature, its retention at a definite temperature for a definite length of time, and, also, its raising or lowering in temperature at a certain definite rate.

All such conditions may affect the strength, hardness, ductility, malleability and other properties of the metal or alloy. Usually, modern alloys are very greatly improved in their properties by suitable heat-treatment.

**Heavy Platinum Metals.**—These are: osmium, iridium, platinum.

**Heckenham Metal.**—A nickel-silver alloy containing: copper, 56% ; nickel, 44%. Used for electric resistance elements, etc.

**Hecla Steel.**—(See Nickel-Chromium-Molybdenum Steels.)

**Hematite.**—A columnar, granular crystallised metallic oxide, steel-grey, iron black, or red ferric ( $Fe_2O_3$ ). It is one of the most important ores of iron.

**Heddur.**—A German aircraft aluminium alloy similar to duralumin.

**Hercules Metal.**—A form of aluminium brass. Approximate composition: copper, 67% ; zinc, 31% ; aluminium, 2%. It casts well and is hard and strong. Tensile strength (average), 30-35 tons per square inch.

**Heusler's Alloys.**—A series of magnetic alloys introduced by F. Heusler in 1903. A typical Heusler alloy is: copper, 55% ; aluminium, 15% ; manganese, 30%.

**Hiduminium.**—An important British aluminium alloy. It was developed in the first instance by the Rolls-Royce Company for motor-racing work, and was first introduced into motor engineering on a large scale by the Armstrong-Siddeley Company.

The alloy is produced by High Duty Alloys, Ltd., of Slough, from whence it derives its name,—*Hi-du-minium*.

Hiduminium alloys vary in composition, there being many types.

**High-Speed Tool Steels.**—These comprise carefully-made steels alloyed with tungsten (12-22%), chromium (2-6%), vanadium (0.3-0.5%), and cobalt. These steels do not soften even at red heat. Hence tools made from them retain their cutting edges at elevated temperatures and can be run at far higher speeds than can tools made from ordinary carbon steels.

**High Tin Bronze.**—(See Phosphor-Bronze.)

**Holmium.**—Metallic element. Chemical symbol, Ho ; At. No. 67 ; At. Wt. 163.5.

It is doubtful whether this element, which is related to dysprosium, has ever been prepared in any state of purity. Its oxide was discovered by P. T. Cleve in 1879, and the con-

tained metal was named by him Holmium, from the town of Stockholm.

**Homburg's Alloy.**—Composition: bismuth, 3 parts; lead, 3 parts; tin, 3 parts. M.P. 251° F. Silvery-white in colour. Used for reproductions of medals.

**Honda Steels.**—A newly-introduced type of magnet steel, having great magnetic retentive powers. It comprises steel alloyed with cobalt (15-36%), nickel (10-25%), titanium (8-25%), and sometimes, also, small amounts of aluminium. Owing, however, to their cost of production, the "Honda" alloys have not been much used.

Named after Professor Honda.

**Horbachite.**—A sulphide mineral from which nickel is obtained. Chemical symbol  $(\text{FeNi})_2\text{S}_3$ .

**Horn Silver.**—This is not a metal, but a naturally-occurring form of silver chloride,  $\text{AgCl}$ . It is so named because of its horny appearance.

**Hoskin Alloy.**—A nickel-chromium alloy used in electrical thermometers as the positive element of a thermocouple. It contains 10% of chromium.

**Hotspur Steel.**—A chrome-nickel steel of high corrosion-resistance. Contains 15-20% of chromium and 20-25% of nickel.

**Howe's Scale.**—A scale of temperature indicating the appearance of incandescent bodies, such as strongly heated metals, to the naked eye. It is :

	Deg. C.	Deg. F.
Lowest visible red in the dark .	470	878
Dull red . . . . .	550	942
Cherry red . . . . .	625	1157
Full cherry red . . . . .	700	1292
Light red . . . . .	850	1562
Full yellow . . . . .	975	1787
Light yellow . . . . .	1050	1922
White . . . . .	1150	2102

The above figures are, of course, only intended to comprise rough approximations of the temperature of the incandescent mass of metal.

**Hoyle's Alloy.**—A white metal used for pivot bearings in machinery, etc. Composition: tin, 24 parts; antimony, 6 parts; lead, 22 parts.

**Hubnerite.**—One of the tungsten minerals. Chemical symbol,  $(\text{Mn.Fe})\text{O}.\text{WO}_3$ .

**Hulot's Alloy.**—This comprises an ordinary 50 : 50 lead-tin solder with 12½%, 25% or 50% of added zinc amalgam. Sometimes used for soft soldering.

## HYBLUM

**Hyblum.**—A foreign alloy of the aluminium-magnesium-silicon type. Can be heat-treated. Tensile strength about 20 tons per square inch.

**Hycc.**—Trade name for a high carbon chromium, non-distorting tool steel. (See **Neor** and **Vital.**)

**Hydrargyrum cum Creta.**—(See **Mercury-with-Chalk.**)

**Hydronalum.**—A German aluminium alloy of which there exist many types. It contains from 5% to 10% of magnesium and from 0.3% to 0.5% of nickel, the remainder being aluminium.

**Hydrone.**—An alloy which generates hydrogen gas in contact with water. Composition: lead, 66%; sodium, 34%.

**Hydrozincite.**—One of the zinc oxide ores. Chemical symbol,  $3\text{ZnCO}_3 \cdot 2\text{H}_2\text{O}$ . 47.58% Zn.

**Hyman Alloy.**—An aluminium alloy containing: silicon, 0.8%; copper, 3%; magnesium, 0.5%; nickel, 0.5%—remainder aluminium. When heat-treated, it has a tensile strength of about 35,000 lb. per square inch.

**Hypernik.**—A nickel-iron alloy of high magnetic permeability. It contains 50% of nickel.

## I

**Igedur.**—A German aluminium alloy. The same as duralumin.

**Ileanite.**—An iron-silicon alloy of Italian origin. Is non-corrosive and similar to **Tantiron** (which see).

**Illinium.**—Metallic element. Chemical symbol, Il; At. No. 61. Discovered almost simultaneously in 1926 by Hopkins (in America) and Rolla and Fernandes (in Italy). Named "Illinium" by Hopkins and "Florentium" by Rolla and Fernandes. The former name has now been almost universally accepted.

Practically nothing is yet known about the properties of this metallic element, except that it is a member of the "rare-earth" series of metals.

**Illium.**—A strong, resistant nickel-containing alloy. It has been made use of in the construction of pressure-resisting chambers and experimental laboratory pressure apparatus. Composition: nickel, 61%; copper, 6%; chromium, 21%; molybdenum, 5%.

**Ilmenite.**—A titanium-bearing mineral. (See **Rutile.**)

**Imitation Gold Leaf.**—Name sometimes applied to Leaf Brass or Dutch Metal.

**Imitation Manganése Bronze.**—Sometimes used as a cheap casting alloy. It is in reality a brass alloy. Composition:

copper, 55% ; zinc, 43%, plus very small amounts or traces of tin and aluminium.

**Imitation Platinum.**—Several alloys have been devised for this purpose.

The two following are typical :

- (a) brass, 120 parts ; zinc, 75 parts.
- (b) brass, 100 parts ; zinc, 65 parts.

**Imitation Silvers.**—These are generally copper-nickel alloys containing zinc, cobalt, cadmium and other metals.

In this Dictionary they are entered under their individual names. (See **Chinese Silver**, **White Alloy**, **Parisian Metal**, **Baudoin's Alloy**, etc.)

**Inalium.**—A French aluminium alloy. Composition : silicon, 0.5% ; magnesium, 1.2% ; cadmium, 1.7%—remainder aluminium. When heat-treated, it has a tensile strength of 26,000 lb. per square inch and a Brinell hardness of 50 to 60.

**Inconel.**—An alloy containing nickel, 80% ; chromium, 14% ; iron, 6%. Is particularly resistant to brine, salt solutions and food acids, and is now being used for the making of food-processing equipment. It also has a high degree of heat-resistance and it is employed for the manufacture of electrical heating equipment.

**Indium.**—Metallic element. Chemical symbol, In ; At. No. 49 ; At. Wt. 114.8 ; M.P. 155° C. ; Sp. Grav. 7.4 ; Sp. Ht. 0.05695 ; Coef. Exp. 0.0000459. Occurs in minute quantities in certain zinc blende. Discovered in 1863 by two German chemists, T. Reich and F. Richter, who named it "indium" in reference to the bright indigo-blue lines which characterise its spectrum.

Indium is a silver-white, lustrous, ductile metal softer than lead. It leaves a mark when drawn across paper. Slowly decomposes water at ordinary temperatures, and therefore rapidly oxidises in moist air. In chemical characteristics, it is very much akin to gallium.

**Ingot.**—A mass of metal which has been cast in a mould.

(From the Anglo-Saxon *in*, in ; *geotan*, to pour.)

**Invar.**—This is a nickel steel containing 0.5% of carbon, 0.5% of manganese, 36% of nickel and negligible quantities of phosphorus, sulphur and other elements. It is manufactured by the open-hearth, furnace or by crucible methods and melts at 1400° C. It can be forged, turned, rolled, filed and drawn. It takes a high polish and it withstands the corrosive action of water. Electrical resistivity is about 18 microhms per centimetre—approx. 8 times that of pure iron. It becomes paramagnetic at about 165° C., but normally it is ferromagnetic. The coefficient of linear expansion between 0° and 40° C. is about one-millionth for ordinary Invar. Above 200° C. its expansion approximates to that of Bessemer steel. It is

## IRIDISED ASBESTOS

manufactured in three commercial grades and is subject to changes in length, following cooling from a high temperature. Its tensile strength varies from 22.5 to 36 tons per square inch and its Brinell hardness number is 160, scleroscope hardness 19, and its modulus of elasticity is 22,500,000.

Thus, Invar is practically completely non-expansible, and, as such, is made use of in the manufacture of clock pendulums, thermostat elements, internal-combustion engine parts and the like. It has a bright silvery appearance, and does not tarnish easily.

The name *invar* was originally coined as a contraction of the word "invariable." (See **Elinvar**.)

**Iridised Asbestos.**—Consists of good quality asbestos fibre permeated with metallic iridium. Prepared by soaking asbestos in a solution of iridium chloride and then by heating it strongly. Similar in properties to **Platinised Asbestos** (which see).

**Iridium.**—Metallic element. Chemical symbol, Ir; At. No. 77; At. Wt. 193; M.P. 2000° C.; B.P. 2850° C.; Sp. Grav. 22.38; Sp. Ht. 0.0323; Coef. Exp. 0.000007.

One of the platinum group of metals. Discovered in 1802-3 by S. Tenant, who gave it its name from the Greek *iris*, a rainbow, in reference to the varying colours of its chemical salts.

Iridium occurs in the metallic state, alloyed with crude platinum to the extent of about 4%. It is a greyish-white, lustrous metal, which, in common with rhodium, is not appreciably attacked by any acid or mixture of acids. It is absolutely unoxidisable in air, even at red heat, and is thus the most stable and resistant of metals. Iridium has a hardening effect on platinum, and platinum-iridium alloys are frequently in use, such alloys containing between 5% and 20% of iridium. If the latter proportion of iridium is exceeded, the alloy becomes exceedingly difficult to work. Platinum-iridium wire coupled with pure platinum wire is used in thermo-couples for estimating temperatures up to 1000° C.

An alloy containing 10% iridium and 90% platinum was selected by the International Committee on Weights and Measures in order to preserve the standards of weight and length.

At very high temperatures, iridium is somewhat volatile. Hence, iridium-platinum alloys when constantly heated to such temperatures tend to lose their iridium content and to decrease in weight.

**Iridium Black.**—A velvety black powder consisting of finely divided metallic iridium. Prepared by precipitating iridium tetrachloride with chemical reducing agents. Has similar properties to **Platinum Black** (which see).

**Iridium Sponge.**—A spongy form of metallic iridium prepared by strongly heating ammonium chloroiridate. Similar to **Platinum Sponge** (which see).

**Iridosmium (or Iridiosmine).**—(See **Osmiridium**.)

**Iron.**—Metallic element. Chemical symbol, Fe (from the Latin *ferrum*). At. No. 26; At. Wt. 56; M.P. 1530° C.; B.P. 2450° C.; Sp. Grav. 7.8; Sp. Ht. 0.1140; Coef. Exp. 0.00001123; Therm. Cond. (Silver = 100) 11.9; Elec. Cond. at 0° C. (Mercury = 1) 9.68. (The foregoing data are for pure metallic iron only.)

Iron is the most abundant and useful of metals. It has been known from prehistoric times, and in its various forms, such as cast iron, wrought iron, steel, and alloy steels, it is the metal upon which civilisation has been built up.

Occurrence: Iron occurs in enormous quantities in Red Hæmatite or Specular Iron Ore,  $Fe_2O_3$ ; Brown Hæmatite,  $2Fe_2O_3 \cdot 3H_2O$ ; Magnetic Iron Ore (Lodestone),  $Fe_3O_4$ , and Spathic Iron Ore,  $FeCO_3$ . It also occurs in small amounts in the free state. It is frequently present in large amounts in meteorites.

Pure iron is a white, lustrous metal, which is capable of taking a high polish. In damp air it soon rusts. It is more difficultly fusible than wrought iron (the purest commercial form of iron), but at red heat it softens and can be readily welded. Perfectly pure iron is useless for industrial purposes, and the physical properties usually associated with iron are, in reality, those of iron admixed with some definite type of impurity, such as carbon. These various types of iron—*Pig Iron*, *Cast Iron*, etc.—should be referred to under their separate headings. Iron is the most magnetic of metals. The metal is acted upon by most acids, but in nitric acid assumes an inert or “passive” condition.

**Iron Amalgam.**—It is doubtful if true iron amalgam exists. A compound said to be iron amalgam is prepared by grinding 1 part of finely-divided iron powder with 2 parts of mercury chloride and 2 parts of water, adding, also, a few drops of metallic mercury. The product takes the form of a greyish, metallic-looking powder.

**Iron and Steel, Composite.**—(See **Steel-faced Iron**.)

**Iron, Spongy.**—A plastic iron invented by Dr. Hans Vogt which is lighter and more economical to produce than lead and which is used in place of lead in many applications. The spongy metal is made by solidifying powdered iron at temperatures above 2000° F. in an atmosphere of hydrogen that prevents the formation of oxides. Tiny cavities that appear in the finished product provide its plastic properties. (See **Ferrocast**.)

## IRON, STEEL-FACED

**Iron, Steel-Faced.**—(See **Steel-Faced Iron.**)

**Ironac.**—A silicon steel containing about 14% of silicon. Used in the chemical industry on account of its great acid resistance.

**Iron Pyrites.**—(See **Pyrite.**)

**Ironier's Bronze.**—A 50 : 50 copper-tin alloy containing 1% to 2% of mercury.

**Isoperm.**—A nickel-iron alloy of extremely low hysteresis factor. Used for the loading-coil cores of cables.

**Italsil.**—An Italian aluminium alloy similar to **Silumin** (which see).

**Izod Test.**—A standard test of a metal's resistance to impact.

The test-piece of metal (a square bar of 1 cm. side) has a notch in it of 2 mm. depth. The sides of the notch have an angle of 45° and the base of the notch forms a rounded groove of 0.25 mm. radius. This is held in a vice which forms part of the testing machine, and it is struck with a pendulum-like hammer operating from a given distance. The force required to break the metal is then determined and is expressed in foot-pounds of energy. A good steel gives an Izod number of about 45 foot-pounds.

## J

**Jacoby's Alloy.**—A white bearing or anti-friction metal. Composition : tin, 85% ; copper, 5% ; antimony, 10%.

**Japanese Blue Gold.**—Composition : gold, 1-10 parts ; copper, 99-90 parts.

**Japanese Brass.**—This consists of an alloy of 10 parts copper and 8 parts zinc. It is also known as "Siachu."

**Japanese Bronze.**—(See **Chinese Bronze.**)

**Jargonium.**—Name given by H. C. Sorby in 1869 to a hypothetical metal supposed to exist with zirconium in the semi-precious stone *jargon*. It was shown not to exist.

**Joujou Gold.**—A 6-carat gold formerly employed in Germany for electro-gilding.

## K

**Kainite.**—A mineral yielding magnesium. Chemical symbol,  $MgSO_4 \cdot KCl \cdot H_2O$ .

**Kanthal Alloys.**—A series of alloys for electric fire elements. They contain varying amounts of chromium, cobalt, and aluminium.

**Kara-Kane.**—A Japanese bell-metal. Composition : copper, 10 parts ; tin, 10 parts ; iron, 0.5 parts ; zinc, 1.5 parts.

**Kennametal.**—A series of hard, carbide alloys used for metal-cutting tools, particularly for machining steel and other metals. The basic ingredient of steel-cutting grades of this metal is the new substance corresponding to the chemical formula  $WTiC_2$ . This compound produces fine-grained, hard metal compositions, not subject to the grain growth experienced in the manufacture of some hard tool compositions. It is made in three grades, KH, KM, and KS, which are the hard, medium and soft grades respectively.

**Key Metal.**—A type of bronze used for keys, etc. Average composition: copper, 80% ; tin, 10% ; lead, 5% ; zinc, 2%.

**Kienmayer's Amalgam.**—An "electric amalgam" used in frictional machines. Composition: zinc, 1 part ; tin, 1 part ; mercury, 2 parts.

**Kieserite.**—One of the minerals producing magnesium. Chemical symbol  $MgSO_4 \cdot H_2O$ .

**Kingston's Metal.**—A white bearing or anti-friction metal. Composition: tin, 88% ; copper, 6% ; mercury, 6%.

**K. Monel.**—Monel containing about 4% of aluminium. It is readily heat-treatable, and can be hardened by such treatment. Tensile strength about 70 tons per square inch.

**Kneiss' Alloy.**—A lead-base anti-friction bearing metal. Composition: lead, 42% ; tin, 15% ; copper, 3% ; zinc, 40%.

**K.S. Magnet Steel.**

**K.S. Piston Alloy.**—An aluminium piston alloy made by K. Schmidt, of Germany, from whose initial letters it derives its name. It has a Brinell hardness of 120–140, and a tensile strength (when heat-treated) of about 40,000 lb. per square inch. Composition: silicon, 12% ; copper, 4.5% ; magnesium, 0.7% ; manganese, 1.2% ; nickel, 1.5%—remainder aluminium.

**Kunheim.**—A mixture containing hydrides of cerium earth metals. Mischmetal mixed with aluminium and magnesium is heated in an atmosphere of hydrogen to 500° C. in an electric muffle furnace. An analysis of this shows the following composition :

Cerium	.	.	.	.	.	30%
Lanthanum, etc.	.	.	.	.	.	49%
Magnesium	.	.	.	.	.	10%
Aluminium	.	.	.	.	.	1%
Iron	.	.	.	.	.	1.5%
Hydrogen	.	.	.	.	.	1.3%
Silicon	.	.	.	.	.	0.5%

**Kunial Brass.**—A special brand of brass produced by I.C.I. Metals Ltd. It is strengthened and hardened by cold working and is sometimes referred to as Temper Hardening Brass. It

## KUPRODUR

has a rather high copper content (about 70%) and can be worked both hot and cold. In the latter case it must be heated to 800° C. and rapidly cooled to soften it. The usual procedure for brass annealing renders it hard. It machines in the same way as any other 70% copper brass, though according to the degree of cold working its strength can be raised in successive stages from about 21 tons to 65 tons with corresponding Brinell values of 68 to 208.

**Kuprodur.**—A copper-nickel-silicon alloy containing 98.75% copper, 0.75% nickel, and 0.5% silicon. Used for locomotive firebox construction.

## L

**Lake Copper.**—Term applied to refined copper produced from ores obtained in the vicinity of Lake Superior. It is usually exceptionally pure metal.

**Lanthanium.**—An old name for Lanthanum. Now obsolete.

**Lanthanum.**—Metallic element. Chemical symbol, La; At. No. 57; At. Wt. 139; M.P. 810° C.; Sp. Grav. 6.1598; Sp. Ht. 0.04485.

Discovered in 1839 by Mosander, who named it from the Greek *lanthanein*, to be concealed, in reference to the difficult task of elucidating its nature.

Lanthanum is one of the rare earth metals. It occurs in the ores Cerite, Orthite and Gadolinite. Also in Lanthanite, an American ore.

Pure metallic lanthanum is rare. It is a white metal, fairly malleable and ductile. It tarnishes rapidly even in dry air, and when heated in air to 445° C. it takes fire and burns, giving a mixture of lanthanum oxide and lanthanum nitride. In moist air, it speedily becomes coated with white crusts of lanthanum hydroxide. It decomposes water, with the evolution of hydrogen and the formation of lanthanum hydroxide. It is easily dissolved by acids.

One alloy of lanthanum with aluminium, of the composition  $\text{LaAl}_3$ , does not decompose water, and, moreover, this alloy is stable in air and highly resistant to acids. Its iron alloys are exceedingly hard.

On account of the rarity of the metal, lanthanum has no uses at present. It is, however, a metal with decided "possibilities."

**Lantz Iron.**—This contains 3% of carbon, 0.9% of silicon, 0.35% of phosphorus, 0.7% of manganese. It has a tensile strength of 20 tons per square inch and high shock-resisting properties.

**Lautal.**—A modern aluminium alloy of German origin. Com-

## LEAD-BEARING STEELS

position : copper, 4.7% ; manganese, 0.5% ; silicon, 1-2% ; remainder aluminium. When well worked and heat-treated, this alloy gives a tensile strength of 25 tons per square inch. Much used in present-day aero work.

**Lead.**—Metallic element. Chemical symbol, Pb (from the Latin *plumbum*). At. No. 82 ; At. Wt. 207 ; M.P. 326° C. ; B.P. 1525° C. ; Sp. Grav. 11.33 ; Sp. Ht. 0.0315 ; Coef. Exp. 0.0000292 ; Therm. Cond. (Silver = 100) 8.5 ; Elec. Cond. at 0° C. (Mercury = 1) 4.8.

An anciently-known metal. Is referred to in the Bible and was worked by the Egyptians. The alchemists connected it with the planet Saturn, and represented it by a scythe, the symbol for Saturn. The ancient Romans much used it for making water-pipes, etc., but they seem to have confused it with tin.

Occurrence : The chief ore of lead is Galena, PbS, which is the commercial ore, but Cerussite, PbCO<sub>3</sub>, is not uncommon. Lead is a bluish-grey metal with a bright metallic lustre when freshly cut, but this lustre soon disappears owing to the metal becoming covered with a film of oxide and carbonate. It also acquires this film when placed under water. The metal is soft enough to be indented by the finger-nail. It leaves a grey streak when drawn across paper. Traces of antimony, arsenic, copper and zinc harden lead. Lead is not sufficiently malleable to be hammered into foil, but it can be rolled into that condition. It is not very ductile. Under a pressure of 32 tons per square inch the metal melts at ordinary temperatures. The metal alloys readily with tin, zinc, antimony, etc., forming very useful alloys. It is chemically reactive, but is fairly resistant to hydrochloric and sulphuric acid. All the chemical compounds of lead are poisonous. Metallic lead is slightly soluble in water containing traces of carbonic acid gas.

**Lead Amalgam.**—Prepared by rubbing lead filings with mercury in a mortar or by pouring molten lead into mercury. Has no definite composition. Possesses a brilliant white colour and remains liquid with as much as 33% of lead. A 50 : 50 lead-mercury amalgam can be crystallised, and a piece of clean lead plunged into this will be found to be covered with crystals of this amalgam when withdrawn.

**Lead-bearing Steels.**—Contain free metallic lead, function of which is to reduce friction between chip and tool on machine, and thereby improving machinability. The difficulties associated with the alloying of lead with steel, owing to their mutual immiscibility when molten, have been overcome by the patented Ledloy process. Steels so produced are commercially made with a lead content of 0.18-0.30% lead. The presence of this lead (in finely and uniformly dispersed, almost sub-

## LEAD BRONZE

microscopic condition) in steel, renders such steel much more easily machinable. In addition, the mechanical properties are unimpaired. In this respect such lead addition has considerable advantage over the usual addition of sulphur or phosphorus or nitrogen, or combinations of same for the purpose of improving machinability. Lead-bearing steels are of recent origin, and are giving 30-100% increased production in the manufacture of machined parts. They can be plated, rust proofed, brazed, welded, and heat treated exactly as for lead-free steels. Any steel made by open hearth or electric or crucible processes can be made in leaded grade.

**Lead Bronze.**—Approximate composition: lead, 10% ; tin, 10% ; copper, 80%. Introduced about 1870 and used for railway work.

**Lead Burning.**—The autogenous soldering of lead by melting the edges of lead pieces together and so avoiding the use of solder.

**Lead Tree.**—Name given to a mass of lead deposited in the form of glistening leaf-like crystals upon a strip of zinc suspended in a solution of a lead salt, such as lead nitrate or lead acetate.

**Leaf Brass.**—Similar in composition to **Dutch Metal** (which see).

**Leaf Gold.**—Or gold leaf. A very thin sheet of gold obtained by hammering out the mass metal. It is much used for artistic and decorative work on account of its great permanence. "Gold-beating," as the manufacture of gold leaf is called, is one of the oldest of the arts and has so far defied all attempts at mechanisation. Gold leaf as thin as 0.000004 of an inch has been obtained. Very thin "leaves" of gold transmit green light.

**Le Chatelier Thermocouple Alloy.**—An alloy used by the French scientist, Le Chatelier. Employed for measuring high temperatures. Composition: platinum, 90% ; rhodium, 10%.

**Ledloy.**—Registered name given to lead-bearing steels manufactured by patented process. (See **Lead-bearing Steels.**)

**Lemarquand's Alloy.**—A supposedly non-oxidisable alloy. Composition said to be: copper, 75 parts ; nickel, 14 parts ; cobalt, 15 parts ; tin, 18 parts ; zinc, 72 parts.

**Lemel.**—Jewellery-trade term for scrap silver turnings, filings, etc.

**Leucopyrite.**—One of the arsenical minerals. Chemical symbol,  $\text{Fe}_3\text{As}_4$ .

**Levol's Alloy.**—A silver-copper alloy containing 718.93 parts of pure silver per 1,000 of alloy. M.P. 870.5°C.

**Lewis's Metal.**—A fusible alloy. M.P. 138°C. ; Sp. Grav. 8.345. Composition: tin, 1 part ; bismuth, 1 part. The

alloy expands considerably on solidifying. It is brittle and can be pulverised to a fine powder.

**Ley Pewter.**—A variety of pewter formerly used for making inkstands, measures and similar articles. Composition: tin, 80% ; lead, 20%.

**Lichtenberg's Metal.**—Fusible alloy. M.P. 91.6° C. Composition: bismuth, 5 parts ; lead, 3 parts ; tin, 2 parts.

**Light and Heavy Metals.**—It has often proved difficult to decide where to draw the boundary line between light and heavy metals. This dividing line has at times been arbitrarily fixed by some writers at specific gravities between 3 and 5. The modern tendency, however, is to fix this boundary line between light and heavy metals at the specific gravity of 3.8. Thus metals having a specific gravity of more than 3.8 would be considered to be "heavy." The matter, however, has not yet been definitely decided upon.

**Light Platinum Metals.**—These are : ruthenium, rhodium and palladium.

**Lighter Flints.**—(See **Pyrophoric Alloys** and **Ferro-Cerium**.)

**Linnaeite.**—A sulphide mineral containing nickel. Chemical symbol,  $(\text{NiCo})_3\text{S}_4$ .

**Linotype Metal.**—A special form of type metal used for casting the type in linotype machines. Composition: lead, 85% ; antimony, 13% ; tin, 2%.

**Lipowitz's Metal.**—Composition: cadmium, 3 parts ; tin, 4 parts ; bismuth, 1.5 parts ; lead, 8 parts. Softens at 112° C. and melts completely at 122° C. Has a silvery-white appearance and is useful for soldering Britannia metal, tin and lead, and, also, for taking casts of small and delicate objects.

**Liquid Gold.**—Many of the so-called "liquid golds" consist merely of a paint made up with tin sulphide, which has a lemon colour. True liquid gold, however, consists of a resinous compound of gold dissolved in a mixture of essential oils. When coated on to pottery and fired in a high-temperature furnace, it produces a brilliant and imperishable film of gold, the exact colour of which can be varied by altering the composition of the gold compound.

Likewise, aluminium paint is sometimes spoken of as "liquid silver," true liquid silver (or, more correctly, liquid platinum) is a similar compound to the above but containing platinum instead of gold. When fired in a furnace it gives on pottery a brilliant, lustrous layer of metallic platinum.

**Liquid Platinum.**—(See **Liquid Gold**.)

**Liquid Silver.**—An old name for **Mercury** (which see). See also **Liquid Gold**.)

**Lithium.**—Metallic element. Chemical symbol, Li ; At. No. 3 ; At. Wt. 7 ; M.P. 186° C. ; B.P. 1400° C. ; Sp. Grav. 0.534 ;

## LITTLE'S ALLOY

Sp. Ht. 0.941; Elec. Cond. at 0° C. (Mercury = 1) 10.69.

Occurrence: in many spring waters, and in a few minerals such as Lepidolite or Lithium Mica. The metal was first prepared in 1818 by Davy after its oxide, lithia, had been discovered in the previous year by A. Arfvedson. The metal was named by the chemist Berzelius from the Greek *lithos*, a stone, in significance of the hard stony minerals from which it had been extracted.

Lithium is a silvery-white metal when freshly cut and having a slight yellow cast. Lithium metal is distinguished not only by being the lightest of all metals, but, also, by constituting the lightest solid material known. It floats on petrol, which itself floats on water. Lithium can be cut by a knife, but it is harder than its related metals, potassium and sodium. The metal may be pressed into wire, and two pieces of the metal may be made to adhere at ordinary temperatures by pressing them together. At a temperature above its melting point, Lithium takes fire and burns with a white light. The metal decomposes water at ordinary temperatures, evolving hydrogen and forming lithium hydroxide. Hence, when exposed to moist air, it quickly becomes covered with a film of hydroxide. It is normally stored under oil. Heated in nitrogen, it forms lithium nitride.

Lithium metal is without use at the present day. Some alloys of the metal with beryllium, aluminium, etc. have been made, but these are also useless.

**Little's Alloy.**—A mirror metal, formerly used for instrument-mirror making. Composition: copper, 69.01 parts; tin, 30.82 parts; zinc, 2.44 parts; arsenic, 1.83 parts.

**Lode Tin.**—“Lode” or “Vein” tin is that which has been derived from lodes or veins in the rocks, as, for example, the world-famed Cornish tin. (See Stream Tin.)

**“Loded” Irons.**—All-pearlite grey irons carrying 1% to 4% chromium with molybdenum if required. Heat resisting. Brinell hardness, 300 to 450. Tensile strength, 16 to 19 tons per square inch.

**Lo-Ex.**—A nickel-aluminium alloy, so-called because it has a lower rate of expansion than that of any ordinary aluminium alloy.

**Lehys.**—A type of mild steel possessing a high magnetic permeability. Used for transformer cores and the like.

**Loilingite.**—One of the arsenical minerals. Chemical symbol,  $\text{FeAs}_3$ .

**Low Brass.**—Average composition: copper, 80%; zinc, 20%. It has a high ductility and a bright golden colour. Is frequently used in the production of cheap jewellery and small

articles of hardware. It has a good corrosion resistance and is very malleable.

**Low Tin Bronze.**—(See Phosphor-Bronze.)

**Luna.**—An alchemical name for silver.

**Lutecium.**—Metallic element. Chemical symbol, Lu ; At. No. 71 ; At. Wt. 175. An extremely rare metal discovered in 1907 by G. Urbain, and named from *Lutéce*, an old name for Paris. It is a grey metal, similar to Ytterbium, but little is known about it.

**Lynite.**—The proprietary or trade name of a range of copper aluminium alloys consisting of 9-13.5% copper, the balance being aluminium and sometimes small percentages of magnesium and iron. The melting point of these alloys is about 550-600° C. They have a rather wide melting temperature range, and the exact melting temperature depends on the copper content, which in turn depends on which Lynite alloy is used. The Lynite alloys are made by the Aluminium Corporation of America, Pittsburgh, and the Niagara Falls Smelting and Refining Corporation of Buffalo, N.Y. These alloys can be welded, but a special flux must be used.

## M

**Macht's Red Metal.**—(See Macht's Yellow Metal.)

**Macht's Yellow Metal.**—Composition : copper, 35 parts ; zinc, 25 parts. Golden-yellow in appearance. It can be forged at red heat, a characteristic which makes it suitable for the making of certain types of fine castings.

“Macht's Red Metal,” a similar alloy, has the composition : copper, 82 parts ; zinc, 18 parts.

**Mackenzie's Amalgam.**—This is a curious amalgam, for, although it is normally solid at ordinary temperatures, it becomes liquid by friction.

It is made by melting 2 parts of bismuth and 4 parts of lead in separate crucibles. The molten metals are then thrown into two other crucibles each containing 1 part of mercury. When cold, these amalgams are solid, but they will melt when rubbed against each other.

**Magnalite.**—An aluminium alloy of the composition : aluminium, 94.2% ; copper, 2.5% ; zinc, 0.5% ; magnesium, 1.3% ; nickel, 1.5%. It has a tensile strength of about 30,000 lb. per square inch and a specific gravity of 2.8. It is a light alloy, similar, in some respects, to “Y” alloy, and is of American origin.

**Magnallium.**—The name given to a group of aluminium-magnesium alloys containing from 2% to 31% of magnesium.

## MAGNESIUM

It is lighter than aluminium, and has mechanical properties somewhat similar to brass.

The alloy is less corrodible than pure aluminium and it can readily be turned. It has a greater tensile strength than aluminium. Magnalium containing about 30% of magnesium has important uses for scientific instruments, and is the most brilliantly reflecting alloy.

**Magnesium.**—Metallic element. Chemical symbol, Mg ; At. No. 12 ; At. Wt. 24 ; M.P. 632° C. ; B.P. 1120° C. ; Sp. Grav. 1.741 ; Sp. Ht. 0.245 ; Coef. Exp. 0.00002694 ; Therm. Cond. (Silver = 100) 34.3 ; Elec. Cond. at 0° C. (Mercury = 1) 22.84.

Occurrence : in Magnesite,  $MgCO_3$ , Kieserite,  $MgSO_4 \cdot H_2O$ , and Carnallite,  $MgCl_2 \cdot KCl \cdot 6H_2O$ . Also in asbestos, meer-schaum, talc, etc. The metal was first prepared in impure form by Davy in 1808. He called it "magnium." Later it was given its present name of magnesium, from the mineral, magnesite.

Magnesium is a silvery-white metal which does not tarnish readily in dry air but which becomes covered with a white film of oxide in moist air. It is a fairly hard metal, malleable, but not very tough. Heated in air, it takes fire, burning with a dazzling white light which is very rich in ultra-violet rays. It is much used in pyrotechny for this purpose and also in wartime for the production of "star shells" and "flash bombs." Recently, it has been combined with "Thermite" (aluminium powder and a metallic oxide) in the making of incendiary bombs.

Pure magnesium is a fairly stable metal, chemically speaking, and, of recent years, it has come into great prominence in view of its usefulness and the cheapening of its manufacturing costs. With aluminium it forms a series of highly important light alloys which are used in aircraft construction and other work, and as a metal it now bids fair to becoming as important as aluminium itself.

**Magnesite.**—One of the minerals producing magnesium. Chemical symbol,  $MgCO_3$ .

**Magnet Steel.**—A wide variety of steel for manufacturing permanent magnets, and containing, according to type, carbon, tungsten, chrome-tungsten, cobalt tungsten, chromium, cobalt chromium, nickel-aluminium, and nickel cobalt titanium.

**Magnium.**—The original name for magnesium, given to it in 1808 by Davy, who first prepared the crude metal.

**Magnolia Metal.**—A white metal alloy for bearings. Has been used chiefly in marine and railway work, since it stands well up to heavy bearing pressures. Composition : lead, 78% ; antimony, 16% ; tin, 6%. The metal takes its name from

## MANGANESE

the trade-mark of its original manufacturers—a mangolia flower.

“Tandem” metal has a similar composition.

**Malachite.**—One of the copper minerals found in the oxide ores. Chemical symbol,  $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ . 57.3% Cu.

**Malleability.**—The degree to which a metal can be flattened out in all directions by rolling or hammering. The malleability of a metal depends upon its toughness and, also, upon its tensile strength. Metals having coarse crystalline structures are not malleable. Hence, any impurity in a metal or any mechanical or physical action to which it is subjected which results in an increase of its coarseness of grain or crystalline structure will decrease its malleability. Some metals increase in malleability with increase in temperature. Gold is the most malleable of all metals, it having been beaten into sheets as thin as 0.000004 in. thick.

The following well-known metals are arranged in order of decreasing malleability : Gold, silver, copper, tin, platinum, lead, zinc, iron, nickel.

The relative malleability of metals is a measure of the thinness to which they may be reduced from the same thickness.

(From the Latin *malleus*, a hammer, in reference to the hammering or beating of malleable metals.)

**Malleable Iron.**—A special grade of cast iron, white when cast, and black after it has been put through the malleabilising process. Its structure consists of a ferritic matrix containing uniformly distributed spots of temper carbon.

**Malloydium.**—An alloy named after its inventor. It is white in colour and acid-resisting. Composition : copper, 59.9 parts ; nickel, 22.8 parts ; zinc, 13.5 parts ; iron, 1 part.

**Manganese.**—Metallic element. Chemical symbol, Mn ; At. No. 25 ; At. Wt. 55 ; M.P.  $1230^{\circ}\text{C}.$  ; B.P.  $1900^{\circ}\text{C}.$  ; Sp. Grav. 7.42 ; Sp. Ht. 0.1217.

The metal was first prepared by Gahn about the beginning of the last century. It was derived from *magnesia nigra*, or “black magnesia” (as manganese dioxide was then called), and, accordingly, the new metal was given the name of “manganesium,” which was afterwards shortened to “manganese” to avoid confusion with “magnesium,” another new metal.

The chief ore of manganese is pyrolusite, or black manganese dioxide,  $\text{MnO}_2$ .

Pure manganese is a white-grey, lustrous metal having a slight reddish tinge. It is harder than iron and will take a high polish. The metal is brittle and is superficially oxidised when exposed to moist air. Heated in nitrogen or ammonia gas, it forms manganese nitride. The metal is soluble in inorganic acids.

## MANGANESE BRASS

Added in small amounts to steel, manganese exerts a very pronounced hardening and toughening effect, hence the nowadays numerous "manganese steels." The pure metal itself, although by no means rare, is more or less a curiosity at present. Its best-known compound, manganese dioxide, has been used since the times of the Romans for decolourising or "bleaching" glass. Potassium permanganate is another well-known compound containing manganese.

**Manganese Brass.**—(See **Manganese Bronze.**)

**Manganese Bronze.**—This is a form of brass containing about 60% of copper and 40% zinc, together with a little manganese and iron. Typical composition: copper, 56% ; zinc, 41.5% ; manganese, 0.25% ; aluminium, 0.25% ; iron, 1% ; tin, 1%. It has a tensile strength of about 30 tons per square inch and is, therefore, as strong as mild steel, in addition to being tougher and more resistant to corrosion. It is sometimes (although less accurately) known as **Manganese Brass**.

**Manganese Copper.**—Also known as Cupromanganese. Name given to a number of copper-manganese alloys of varied proportions. They are silvery-white in colour, have great hardness and fair ductility. The best manganese coppers contain from 10% to 30% of manganese. A typical manganese copper contains: manganese, 25% ; copper, 75%. Other varieties of this alloy contain small amounts of tin, zinc and nickel. It often serves as an addition to copper or copper alloys in order to impart greater strength and density to them.

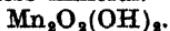
**Manganese Steel.**—Name given to special steels containing upwards of 7% of manganese which are characterised by their extreme toughness and freedom from flaws. Such steels are used for making ore-crushers, grinding wheels, burglar-proof safes, etc. It can be cast, forged and heat-treated in a number of ways.

Steel containing from 2½% to 6% of manganese is more or less worthless, since it is brittle.

**Manganesium.**—An early name for the metal manganese.

**Manganin.**—An electrical high-resistance alloy used for winding resistance coils, etc. Composition: copper, 84% ; manganese, 12% ; nickel, 4%.

**Manganite.**—A manganese mineral. Chemical symbol,



**Manilla Gold.**—An imitation gold. An alloy of copper, zinc and lead. Composition varies.

**Mannheim Gold.**—One of the many "imitation golds." Composition: copper, 83.1% ; zinc, 10.0% ; tin, 6.9%. The composition of Mannheim gold varies considerably, and sometimes the tin is left out. It has a reddish tint.

Also known as "Similor" and "Prince's Metal."

## MEDIUM STEEL

**Marketable Copper.**—A name given in the trade to copper which has been smelted from its ores. It contains approximately 99.5% of copper. Is sometimes known as "Tough Pitch" copper.

**Marlie's Alloy.**—An oxidisation-resisting alloy. Composition : iron, 10 parts ; nickel, 35 parts ; brass, 25 parts ; tin, 20 parts ; zinc, 10 parts. Articles made in this alloy are acid-dipped to give them a resistant surface.

**Martensite.**—Name given to a solid solution of carbon in that variety of pure iron known as "beta-ferrite." It is a typical constituent of steel which has been hardened by quenching. Called after A. Martens, the metallurgist.

**Masurium.**—Metallic element. Chemical symbol, Ma ; At. No. 43.

Discovered (along with the more plentiful rhenium) in 1925 in platinum ores by Noddack and Tacke.

Although the element is a metallic one, practically nothing is known about it at the present time.

**Mathesius's Metal.**—Name given to a lead-strontium alloy which has been used as a bearing metal.

**Matte.**—In lead smelting any sulphur in the charge which does not pass off with the flu gases forms matte with copper and iron.

**Maturing.**—(See Ageing.)

**Mazak.**—The Mazak alloy compositions contain a zinc base of extreme purity. They are used chiefly in connection with die casting. They are thus zinc base alloys. One of the best known is Mazak No. 3, the Mazak No. 5 being discontinued for the time being. The composition of Mazak and Durak (the latter replacing Mazak No. 5) is given in the table below :—

<i>Composition :</i>	<i>Mazak No. 3</i>	<i>Durak</i>
Aluminium . . . . .	4.1	4.1
Copper . . . . .	—	1.0
Magnesium . . . . .	0.04	0.03
99.99 + % Zinc . . . . .	Balance	Balance

*Properties :*

Tensile Strength— tons/sq. in. . . . .	20.75	22.91
Elongation—% on 2 in. . . . .	3.7	2.8
Impact Strength—ft.-lb. . . . .	32	37
Brinell Hardness No. . . . .	74	100
Thermal Expansion per °C. . . . .	$27.4 \times 10^{-6}$	$27.4 \times 10^{-6}$
Melting Point °C. . . . .	381	380.5
Weight—lb./cu. in. . . . .	0.24	0.24

**Medal Metal.**—A brass used for medal stamping purposes.

Composition : copper, 86% ; zinc, 14%. It is fairly soft.

**Medium Steel.**—(See Steel.)

## MEEHANITE

**Meehanite.**—A typical sample of Meehanite Iron contains from 2.4 to 2.7% of carbon, silicon 1.0 to 1.5%, phosphorus 0.1 to 0.2%, sulphur 0.05 to 0.14% and manganese 0.65 to 1.0%. Its tensile strength varies from 20 to 30 tons per square inch. The methods of manufacture resemble those used for cast iron and semi-steel, for the basic materials include steel scrap, coke, limestone, pig-iron and foundry scrap. The cupola used, however, is of special design and exact metallurgical control is necessary in the melting. It is made in 5 grades, Nos. A, B, C, D and E, and they vary in tensile strength from 30,000 lb. for E to 50,000 lb. for A. The A grade may be heat treated to yield a tensile strength of about 75,000 lb. per square inch. Another important advantage possessed by Meehanite is that it is "non-growing" at high temperatures. It is highly resistant to corrosion, abrasion and erosion. Castings may be easily machined and they are uniform. In industry it is particularly used for crankshafts and camshafts, as well as for cylinders and rams of hydraulic presses. It is also used because of its wear-resisting properties for forming, pressing, drawing and stamping dies. It does not crush at its edges and work-hardens on the surface, when a glazed skin forms.

**Melaconite.**—One of the copper minerals found in the oxide ores. It is a black oxide. Chemical symbol, CuO. 75.8% Cu. Sometimes referred to as Tenorite.

**Menachin.**—The original name for Titanium, which was given to this element by W. McGregor when he discovered it in Menachanite, a variety of sand found near Menachan, in Cornwall. (See **Titanium**.)

**Meral.**—A Swiss aluminium alloy. Composition : copper, 3.2% ; magnesium, 0.8% ; manganese, 0.3% ; nickel, 1%—remainder aluminium. Brinell hardness, 16. Tensile strength (heat-treated), 55,000 lb. per square inch.

**Mercury.**—Metallic element. Chemical symbol, Hg (from the Latin *hydrargyrum*, meaning "liquid silver"). At. No. 80 ; At. Wt. 200 ; Freezing Point,  $-38.85^{\circ}$  C. ; B.P.  $357.25^{\circ}$  C. ; Sp. Grav. 13.596 ; Sp. Ht. 0.03312 ; Coef. Exp. 0.000182 (Cubical Expansion) ; Elec. Cond. (Copper = 100) 1.96.

Chief ore : Cinnabar, HgS.

Mercury or Quicksilver was known to the ancients on account of the ease with which it is extracted from its ore, cinnabar. The alchemists were especially attracted by it, and considered it to be a constituent of all metals. On account of the peculiar nimbleness of its globules, they named it "Mercury," after the mythological Mercury who was the fleet-footed messenger of the gods.

Mercury is a silvery-white metal. It is the only metal

known which is liquid at ordinary temperatures, although the metal gallium makes a close second to it. Mercury remains unchanged in dry or moist air. It is not very volatile except when heated. Alkalies have no action upon it, but it dissolves in many mineral acids, as, for instance, nitric acid. All soluble mercury salts and compounds are very highly poisonous, as is, also, mercury vapour itself. In very thin films, mercury appears violet by transmitted light.

Mercury has very many uses in science and industry and also in the arts. It readily dissolves and/or alloys with most metals, such alloys being called "amalgams."

**Mercury-with-Chalk.**—Name given to a preparation containing chalk and mercury which is used in medicine. Known, also, as "Grey Powder." It is prepared by grinding up mercury with chalk and consists merely of very fine globules of metallic mercury which are prevented from coalescing together by the presence of the chalk particles. Its pharmaceutical name is "*Hydrargyrum cum Creta*," which means literally "Mercury with Chalk."

**Mesothorium.**—A radio-active element found in monazite, and used for manufacture of luminous paints for watches and clocks, gun-sights, instruments, etc.

**Metal d'Alger.**—(See **Algiers Metal.**)

**Metal Fatigue.**—(See **Fatigue.**)

**"Metallic" Selenium.**—The light-sensitive variety of the element Selenium, obtained by quickly cooling molten selenium to 210° C., and then by keeping it at that temperature for some time. M.P. 217° C. ; Sp. Grav. 4.5.

"Metallic" selenium is a black, shining material, whose electrical conductivity in daylight is about twice that of its conductivity in the dark. Strictly speaking, the material is more or less entirely non-metallic in nature.

**Metallic Smells.**—(See **Odour of Metals.**)

**Metalline.**—A bronze alloy having the approximate composition : copper, 30% ; aluminium, 25% ; iron, 10% ; cobalt, 35%. It is very ductile, yet hard and enduring.

**Metal of Clay.**—An early name for aluminium, this metal being a constituent of all clays.

**Meter Metal.**—A soft alloy containing 95% tin and 5% antimony.

**Metilure.**—A French iron-silicon alloy of non-corrosive properties. It is similar to **Tantiron** (which see).

**Mild Steel.**—This is ordinary carbon steel containing not more than 0.5% of carbon. It is malleable and can readily be welded. For ordinary "day-by-day and everyday" uses, mild steel is indispensable.

## MILLERITE

**Millerite.**—A capillary, metallic, brass-yellow brittle nickel sulphide (NiS). Named after W. H. Miller (1801-80).

**Minargent.**—A French imitation silver. Composition: copper, 56% ; nickel, 40% ; tungsten, 3% ; aluminium, 1%.

**Minofor Metal.**—A variety of Britannia metal. Composition: tin, 68.5% ; antimony, 18.2% ; copper, 3.3% ; zinc, 10%.

**Miralite.**—An English aluminium alloy. Contains 96% aluminium, 4% nickel. Tensile strength, about 25,000 lb. per square inch.

**Mira Metal.**—A white, acid-resisting metal of somewhat complex composition. It contains: copper, 74.75 parts ; zinc, 0.61 part ; lead, 16.35 parts ; tin, 0.91 part ; iron, 0.43 part ; nickel and cobalt, 0.24 part ; antimony, 6.78 parts.

**Mischmetal.**—An alloy of cerium metals obtained by the electrolytic reduction of crude cerium chloride. It contains cerium and lanthanum, together with small quantities of praseodymium, neodymium and samarium. Alloyed with iron, to increase its hardness, mischmetal is much used in the preparation of pyrophoric alloys for lighting and sparking devices. (See **Pyrophoric Alloys.**)

**Mispickel.**—Most important arsenical mineral. Sometimes referred to as arsenopyrite. Chemical symbol,  $\text{FeS}_2\text{FeAs}_2$ . Contains iron and cobalt.

**Mitia.**—One of the commercial brands of tungsten carbides, made by Firth-Brown. (See **Tungsten Carbide.**)

**Modulus of Elasticity.**—The index of the stretching power of a metal. The force which would be necessary to stretch a piece of metal to double its length if the elasticity of the metal were perfect.

**Moirée Metallique.**—Name given to the surface of sheet tin or tinplate which has been treated with hydrochloric or sulphuric acids, under which treatment the metal surface acquires a peculiar crystalline or "watered silk" appearance. This is sometimes made permanent by being coated with coloured varnishes.

(From the French *moiré*, "watered.")

**Mokumè.**—A Japanese art-material consisting of a laminated or composite sheet of different metals, which has been hammered and surface-worked to give the appearance of wood grain.

**Molybdenite.**—A mineral containing molybdenum. Chemical symbol,  $\text{MoS}_2$ .

**Molybdenum.**—Metallic element. Chemical symbol, Mo ; At. No. 42 ; At. Wt. 96 ; M.P.  $2550^\circ\text{C}$ . ; B.P.  $3200^\circ\text{C}$ . ; Sp. Grav. 8.6 ; Sp. Ht. 0.0659. Chief ores ; Molybdenite,  $\text{MoS}_2$  ; Wulfenite,  $\text{PbMoO}_4$ .

Molybdenum was first prepared (in the form of a metallic powder) in 1790 by P. J. Hjelm. Its name was derived from

the Greek *molybdos*, signifying "leadlike," this being a name which the Greeks applied to galena and all lead ores.

Molybdenum, when pure, is a greyish metal, having a bluish cast, and capable of taking a high polish. It is closely related to chromium in properties. It does not readily oxidise or tarnish in air, and its melting point is even considerably higher than that of platinum. For this latter reason, the pure metal has been extensively employed in the making of the electrodes of transmitting valves, cathode-ray tubes and other high-vacuum devices.

Molybdenum has the property of rendering iron and steel hard without, at the same time, making them too brittle. For this reason, molybdenum is nowadays being increasingly used. Molybdenum steels are employed for making ships' propeller shafts, rifle barrels, and, also, as high-speed tool steels, it being found that such steels do not lose their temper when heated. Molybdenum steels may contain up to ten per cent of the metal, molybdenum.

Compounds of molybdenum are used in dyeing and in pigment making.

**Molybdenum Nickel.**—A nickel-molybdenum alloy containing from 20% to 50% nickel and from 45% to 75% of molybdenum. Used in the manufacture of nickel-molybdenum steels.

**Molybdenum Steel.**—Introduced in 1904 by the French metallurgist Professor Guillet. Such steels may contain up to 10% of molybdenum. They are as hard but less brittle than tungsten steels, and, being particularly shockproof, are employed for making rifle barrels, propeller shafts, etc. They are also used as high-speed steels, i.e. for the making of tools running at very high speeds. Steels containing molybdenum have also been employed for bullet-proofing purposes.

**Molybdite.**—A mineral containing molybdenum. Chemical symbol,  $\text{MoO}_3$ .

**Molyte.**—A mixture of molybdenite, lime and silicon.

**Monazite.**—A natural phosphate of cerium containing thorium and other "rare earth" metals.

**Monel Metal.**—Primarily a nickel-copper alloy containing iron, manganese and other elements. Derived from the smelting of a nickel ore containing copper. It was first introduced in 1905 by the International Nickel Company, and it takes its name from Ambrose Monell, the then President of that organisation.

Monel contains approximately two-thirds of its weight of nickel. A typical analysis of this alloy is: nickel, 68.41%; copper, 29.14%; iron, 1.19%; manganese, 1.02%; silicon, 0.06%; carbon, 0.12%; sulphur, 0.008%.

The metal has a specific gravity of 8.8, Coef. Exp. 0.000015. It is sufficiently magnetic to be attracted to a hand magnet.

## MONTEGAL

Monel is a tough alloy whose mechanical properties can be improved by cold working. It cannot be heat-treated. It has a specific heat of 0.127. It is claimed to be between 10% and 15% stronger than mild steel.

Monel is used at the present time on account of its high oxidisation and corrosion-resisting properties. It is employed frequently in the construction of machinery for the handling of foods and chemical substances. Also for dyehouse, laundry and hospital equipment and the like.

**Montegal.**—A modern aluminium alloy containing 0.95% of magnesium and 0.8% of silicon. Has considerable hardness and can be heat-treated. Tensile strength about 22 tons per square inch.

**Morenosite.**—One of the nickel salts. Chemical symbol,



**Mosaic Gold.**—One of the “imitation golds.” A variety of brass. Composition varies, but the following is typical: copper, 65.3%; zinc, 34.7%.

This must not be confused with the variety of “mosaic gold” which is used as a pigment and which consists of scales of tin sulphide.

**Moss Copper.**—Name given by copper refiners to the fine, green, velvety filaments of impure copper which sometimes line cavities in lumps of the smelted copper.

**Motor Brass.**—A fine-grained brass for automobile parts, etc. Composition: copper, 62–65%; zinc, 31–36%; lead, 2–4%.

**Mottled Pig Iron.**—(See **Pig Iron.**)

**Mousset's Silver Alloy.**—Jewellery alloy. Composition: silver, 27.5%; copper, 59.5%; zinc, 9.5%; nickel, 3.5%.

**Mumetal.**—A nickel-iron alloy containing, also, about 6% of copper in order to facilitate its heat-treatment. Was developed by The Telegraph Construction and Maintenance Co., Ltd. Has similar properties to the “Perm-alloy” series of high magnetic permeability alloys.

**Muntz's Metal.**—A variety of brass containing 60% copper and 40% zinc. It is plastic when hot and, in the absence of tin and other hardening metals, can be extruded through a die when red hot. When used for this purpose, about 1% of its contained zinc is replaced by lead. Was formerly much used for ship-sheathing in place of copper.

The metal was originally devised and patented in 1832 by Mr. George Frederick Muntz, of Birmingham.

Specific gravity, 8.2.

**Mushet's Steel.**—Tungsten steel. A type of steel containing upwards of 3% of tungsten. It is difficult to forge and cannot be welded. It can be cast into the form of tools which can be ground to a very sharp edge.

**Musiv Silver.**—An amalgam which has at times been used for the spurious silvering of brass and copper, the amalgam being mixed with 6 times its weight of bone ash and applied to the metal surface with a rubbing action. Pasteboard, wood, paper and other materials may also be similarly silvered by grinding the amalgam with egg-white, gum water, glue water, etc., and by rubbing it on to the surface to be so treated.

The “Musiv silver” amalgam consists of: tin, 3 parts bismuth, 3 parts; mercury, 1.5 parts.

## N

**Native.**—Metals are said to be in the “native” condition when they are actually found in the metallic state, and not combined with other elements in the form of ores. Gold, platinum, iridium, osmium, palladium, silver and mercury are some of the metals which occur at times in the native condition.

**Naval Brass.**—Composition: copper, 59%; zinc, 40%; tin, 1%.

**Navo Max.**—A cobalt high-speed steel. It is forged at 1125–1150° C. Reheat and set aside to cool. When cold, reground to shape before hardening. Reheat in the low temperature chamber of the furnace slowly, evenly and thoroughly to about 850° C. Transfer quickly to the high temperature furnace working at about 1350–1380° C. Control heating period by a stop-watch. Quench in *dry* air blast. Give secondary hardness by heating to 580–600° C., holding at temperature for about 30 minutes, then place on the floor to cool.

**Needle Antimony.**—Commercial term. Is sometimes applied to antimony sulphide, but NOT to the metal.

**Neodidymium.**—The original name of the metal Neodymium (which see).

**Neodymium.**—Metallic element. Chemical symbol, Nd; At. No. 60; At. Wt. 144; M.P. 840° C.; Sp. Grav. 6.9562.

An important member of the cerium group of rare metals, its chief ore being cerite. Discovered in 1885 by Auer von Welsbach and named by him “Neodidymium” (from the Greek *neos*, new; *didymos*, twins) in allusion to its then constituting a newly-discovered element similar to Lanthanum. Subsequently, the name “neodidymium,” being too much of a tongue-twister, was, by general consent, contracted to neodymium, which is the present-day accepted name of the metal.

Neodymium is a silvery-white metal, with a very slight yellowish hue. It is fairly stable in air, but is said to decompose water slowly in the cold and rapidly at the boiling point, with

## NEOGEN

the evolution of hydrogen and the formation of neodymium hydroxide. The metal alloys with cerium and its related metals.

**Neogen.**—An ornamental metal having a copper base. An imitation gold. Composition: copper, 58 parts; nickel, 12 parts; zinc, 27 parts; tin, 2 parts; aluminium, 0.5 part.

**Neonalum.**—A copper-aluminium alloy containing 6% of copper. Of Swiss origin. Tensile strength, 23,000 lb. per square inch. Brinell hardness, about 100.

**Neo-Ytterbium.** (See **Ytterbium.**)

**Neor.**—Trade name for a high carbon chromium, non-distorting tool steel.—(See **Vital** and **Hycc.**)

**Neu-Silver.**—A nickel or German silver.

**Neutraleisen.**—A German iron-silicon non-corrosive alloy, similar to **Tantiron** (which see).

**Nevada Silver.**—A nickel or German silver.

**New Metal.**—Metal obtained directly from its ores, or alloy newly made-up, in contradistinction to a metal or alloy re-melted from scrap or previously used material.

**Newton's Metal.**—A fusible alloy. M.P. 94.5° C. Composition: bismuth, 8 parts; lead, 5 parts; tin, 3 parts.

**Ni-Tensyl.**—High-strength inoculated grey iron containing nickel. Gives 21 to 24 tons per square inch tensile, which falls to 18 tons in very thick sections. Brinell hardness, 200-240.

**Niccolite.**—One of the nickel arsenides. Chemical symbol, NiAs.

**Nichrome.**—A nickel-chromium alloy which is chemically-resistant and heat-resistant. Used for resistance elements, etc. Composition: nickel, 60%; chromium, 12%; manganese, 2%; iron, 26%.

**Nickel.**—Metallic element. Chemical symbol, Ni; At. No. 28; At. Wt. 59; M.P. 1435° C.; B.P. 2450° C.; Sp. Grav. 8.8; Sp. Ht. 0.10916; Coef. Exp. 0.0000128; Elec. Cond. at 0° C. (Mercury = 1) 7.37; Brinell hardness, 75-95.

Chief ores: Kufernickel or Niccolite, NiAs, Nickel blende, NiS, Nickel glance, NiAsS. Occurs intimately mixed with cobalt ores.

Nickel seems to have been known to the Chinese. Two hundred years ago the Germans applied the term "kupfer-nickel" (false copper) to minerals having the appearance of copper ores but which contained no copper. Such ores were nickel-bearing ones. The name "nickel" is a German one, meaning "the devil." It was first specifically applied to the metal by Cronstedt, in 1751.

Nickel, when pure, is a highly lustrous white metal. It is hard, easily polished, ductile and malleable. Nickel, like

cobalt, is slightly magnetic. Until recent date it was used enormously as a plating metal, since plated nickel gave a fine finish to base metal. Added in small amounts to steel, the metal forms the various nickel-steels which are exceedingly hard and which have been employed for armour-plating purposes, as well as for other uses. In these, the proportion of nickel may be as high as 20%.

Nickel is a most ubiquitous alloying metal. It enters into a large number of alloys of widely varying characteristics and properties, and it is, indeed, as an alloying metal that it is mostly made use of nowadays. A certain amount of pure nickel is employed for the making of instruments, etc.

**Nickel Amalgam.**—A plastic metallic mass made by rubbing an amalgam consisting of 1 part of sodium and 99 parts of mercury with a concentrated solution of nickel chloride. Sometimes used as a metallic cement.

**Nickel Carbonyl.**—Nickel combined with CO. A process based upon the property nickel possesses of combining at low temperatures with CO forming the readily volatile compound known as Nickel Carbonyl  $\text{Na}(\text{CO})_4$ . The process is only applicable to ores and roasted products containing nickel in the form of free oxide.

**Nickel-Chromium-Manganese Steels.**—Similar to the nickel-chromium-molybdenum steels (which see). They are non-magnetic, hard and tough. Brinell hardness, 250 approx. Used for bullet-proof plates and also, in some instances, for the retaining end rings of dynamos.

**Nickel-Chromium-Molybdenum Steels.**—These are chrome-nickel steels "reinforced" with a small amount of molybdenum, which increases their strength without increasing their brittleness. Such steels are tough, resistant to fatigue and shock, and are employed for armour-plating and similar purposes.

The Hadfield "Hecla/134" alloy steel is of this type.

**Nickel-Chromium Steel.**—(See **Chrome-Nickel Steel.**)

**Nickelene.**—An alloy invented by A. L. Goldsmith in 1912. It has a white lustre with a faint reddish-yellow hue. It takes a high polish and is used as an imitation silver. Composition: copper, 55% ; nickel, 12.5% ; zinc, 20.5% ; lead, 10% ; tin, 2%.

**Nickeline.**—A nickel-copper-zinc alloy used in electrical resistances. Composition: nickel, 15% ; copper, 60% ; zinc, 25%.

**Nickel-Silver.**—Also called "German Silver." Contains copper (56-60%), zinc (20%), nickel (20.25%), and sometimes small amounts of cobalt, lead and iron. Inferior qualities contain not more than 7% of nickel.

Owing to its white colour, lustre, toughness, tenacity, malleability, ductility and chemical resistance, any good quality

## NICKEL STEEL

nickel silver or German silver is a very useful metal for ornamental work. It has a high electrical resistance, and is also used for the manufacture of electrical resistance wire, apart from its many other important uses dealt with on other pages.

The nickel or German silvers have a fairly high tensile strength of from 25 to 40 tons per square inch.

**Nickel Steel.**—One of the earliest of the alloy steels, and one of the most important and most used. First employed about 1888. Nickel steels contain nickel in amounts up to 50%. They are hard, tough and resistant and are mostly able to withstand continuous wear and shocks.

Above a nickel content of 2%, 1% of nickel adds about  $2\frac{1}{2}$  tons per square inch tensile strength to the steel up to about 8-10%. The fatigue resistance is also increased.

Steels containing 10-15% nickel are brittle.

The great bulk of nickel steel contains from 2 to 4% of nickel and from 2% to 0.5% of carbon. It is used for varied structural and engineering purposes. Also for seamless tubes of bicycles and motor-cycles, and for car parts, etc.

**Nickel-Tungsten.**—An acid-resisting alloy. Composition varies greatly. Approximate limits are : nickel, 75-90% ; tungsten, 8-25%.

**Nickel White Iron.**—One of the "alloy cast irons" which has a high abrasion resistance. Typical composition : nickel, 1.8% ; chromium, 0.8% ; silicon, 0.5%, these constituting the alloying ingredients of the iron. Its latest development is **Ni-Hard** (which see).

**Nickeltin.**—An alloy composed of 50% of nickel and 50% of tin, made by the new process of corronising, introduced by the Standard Steel Spring Co. of Pennsylvania. The two alloys are applied in layers by the corronising process to steel sheets.

**Nicrosilal.**—This is an austenitic grey iron containing for most purposes about 2% of total carbon, 5% of silicon, 1% of manganese, 18% of nickel, and 2 to 5% of chromium. This iron has an exceptionally high degree of heat and scale resistance at all temperatures up to 1100° C. The alloy is the invention of the British Cast Iron and Research Association, British Patent No. 378508.

**Ni-Hard.**—A white cast iron alloyed with nickel to give great hardness. It contains 4.5 nickel, 1.5% chromium and 0.5% silicon as alloying ingredients. Owing to its great abrasion resistance, it is employed for the casting of grinding wheels, crusher jaws and for similar uses.

**Nillex.**—A low expansion nickel-iron alloy containing about 36% of nickel. Its expansion is not more than  $1\frac{1}{2}$  millionths per degree Centigrade. Used in instrument work, etc.

**Niobium.**—This was the original name of the rare metal **Columbium** (which see). The metal has a strong resemblance to tantalum, and it was originally named "niobium" by its discoverer, H. Rose, in allusion to Niobe, the mythological daughter of Tantalus.

The name "Niobium" (together with the symbol, Nb) is still employed in a number of chemical textbooks and reference works.

**Ni-Resist.**—An alloy cast iron containing nickel (14%), copper (6%), and chromium (2%). Originally developed by adding about 20% of Monel (nickel-copper alloy) to cast iron. It can be made in several varieties and, on account of its high corrosion-resistance, is being much employed in the chemical industries. It is also a heat- and corrosion-resisting cast-iron.

**Nitralloy.**—Two typical analyses of nitralloy steels are as follow: (a) 0.36% carbon, 0.51% manganese, 0.27% silicon, 1.23% aluminium, 1.49% chromium, 0.01% sulphur, 0.013% phosphorus, 0.18% molybdenum.

(b) 0.23% carbon, 0.51% manganese, 0.20% silicon, 1.24% aluminium, 1.58% chromium, 0.011% sulphur, 0.011% phosphorus, 0.2% molybdenum. The annealing temperature of the steel is approximately 540° C. The steel is not weldable by the oxy-acetylene process.

**Ni-Tensyl Iron.**—A variety of alloy cast iron containing about 1.5% each of nickel and silicon. It possesses high tensile strength (25 tons per square inch) and gives sound, fine-grained castings. It is amenable to various heat-treatments and is employed for the production of heavy engineering castings, as, for instance, those of flywheels and the like.

**Nitrided Steel.**—Steel whose surface has been hardened by quenching it in ammonia. The "Nitriding" process was developed in 1920. It gives a glass-hard surface to the steel.

**Nitrosilal.**—This is a silicon-nickel of cast-iron alloy, containing 18% of nickel, 6% of silicon and a small percentage of chromium.

**Noble Metals.**—Name given to gold and the platinum metals (osmium, iridium, platinum, ruthenium, rhodium, palladium) and sometimes, also, to silver in allusion to their great permanence and durability in contact with air, acids and weathering influences.

In contradistinction to the so-called noble metals, all the other common metals (iron, copper, lead, etc.) are referred to as "Base Metals."

**Noheet.**—An anti-friction metal which was at one time known as "tempered lead." Was used as a bearing metal during the Great War when tin was scarce. Average composition: sodium, 1.3%; antimony, 0.11%; tin, 0.08%—remainder lead.

## NOMAG

The tensile strength of "Noheet" is said to be between 13,000 and 15,000 lb. per square inch and its compressive strength some 22,000 lb. per square inch.

**Nomag.**—A non-magnetic cast iron introduced in 1924 by S. E. Dawson. It contains, as alloying ingredients, from 10% to 12% of nickel and from 5% to 6% of manganese. Used for the production of non-magnetic castings of high electrical resistance.

**Non-ferrous Metals.**—Metals or alloys which do not contain iron. (From the Latin *ferrum*, iron.)

**Nongro.**—A nickel-iron alloy containing about 36% of nickel. Its coefficient of expansion is very low, being not more than  $1\frac{1}{2}$  millionths per degree Centigrade. Used for high-grade clocks, instrument work, etc.

**Norium.**—Name given by L. F. Svanberg in 1845 to a supposed new metal associated with zirconium. It was shown not to exist.

**Normalised Steel.**—Steel which has been heated to about 860° C. and then cooled in air. It shows an increase in strength without loss of toughness. Almost any type of steel can be "normalised" in this manner.

**Nugget.**—Name which can be applied to any small, roughly-shaped mass of metal. It is usually given to small lumps of metallic gold which are washed out of sands and gravels. Occasionally, such nuggets are of large size, as, for instance, the "Welcome" nugget which was found in Victoria in the last century and weighed 183 lb.

**Nürnberg Gold.**—An alloy of gold, aluminium and copper. Used for cheap jewellery, since the gold need only be present in small amounts to give the metal a golden colour. Composition very variable.

## O

**Occlusion.**—The property possessed by some metals (in common with other substances) of absorbing gases and retaining them. Palladium will absorb nearly 1,000 times its volume of hydrogen. Gold absorbs 46 times and nickel 15 times their respective volumes of hydrogen. Silver, aluminium, lead, iron, cobalt and other metals absorb hydrogen, oxygen and other gases in varying volumes, particularly when the metals are in powder form. The real nature of metallic occlusion is unknown. (From the Latin *occludere*, to shut up.)

**Odour of Metals.**—Some metals emit a faint but distinctive odour when they are rubbed, particularly in the warm state.

Apart from the case of volatile metals, such as mercury, arsenic, etc., this phenomenon has not been adequately explained.

**Olivine.**—A common mineral, containing magnesium roughly in the proportion of one-half. Main reserves of olivine, estimated at about 23,000,000 tons, are along the eastern seaboard in North Carolina and Georgia, said the report. Extensive deposits of the finest quality also occur in the Twin Sisters mountain region 90 miles north of Seattle, Washington, and in the Puget Sound region of the Pacific Coast.

**Onions' Alloy.**—A fusible metal. M.P. 197° F. Composition: bismuth, 5 parts; tin, 2 parts; lead, 3 parts.

**Open-Hearth Steels.**—Steels which have been manufactured by the "open-hearth" process which consists in smelting the steel in a gas-fired "regenerative" furnace consisting of a shallow trough or "hearth." The idea originated with W. Siemens (1863) and was substantiated by E. Martin (1864). Hence the process is sometimes known as the "Siemens-Martin" process, the steel, also, at times being given that name.

**Ordnance Metal.**—Another name for Gunmetal.

**Oreide (Oroide).**—A French brass having the composition: copper, 82.75%; zinc, 16.40%; tin, 0.55%; iron, 0.30%. Has a beautiful golden colour. Known, also, as "French Gold."

**Ornamental Brass.**—A fine, yellow brass for ornamental casting work. Takes a good polish. Composition: copper, 75%; zinc, 22%; tin, 2%; lead, 1%.

**Orpiment.**—One of the arsenical minerals. Chemical symbol,  $\text{As}_2\text{S}_3$ .

**Osmiridium.**—A native alloy of osmium and iridium (and other related metals) which is exceedingly hard. Used for tipping the gold nibs of fountain pens. Average composition: osmium, 27.2%; iridium, 52.5%; platinum, 10.1%; ruthenium, 5.9%; rhodium, 1.5%. It also contains traces of palladium, copper and iron. It is also known as "Iridiosmine."

**Osmium.**—Metallic element. Chemical symbol, Os; At. No. 76; At. Wt. 191; M.P. 2300° C.; B.P. 2950° C.; Sp. Grav. 22.47; Sp. Ht. 0.03113; Coef. Exp. 0.00000657.

Osmium is one of the platinum group of metals. It invariably occurs in Nature in the metallic condition alloyed with platinum and other metals of the group. The metal was discovered by S. Tennant in 1802-3, and given its name from the Greek *osme*, a smell, in allusion to the peculiar odour of its volatile oxide,  $\text{OsO}_4$ . Osmium is a lustrous, white metal, having a bluish cast. Like platinum, it is unoxidisable, even at high temperatures, and like platinum, also, it can be dissolved by *aqua regia* (a mixture of strong nitric and hydrochloric acids).

## OTTO'S ALLOY

A naturally-occurring alloy of osmium and iridium—"osmiridium"—is exceedingly hard, and is used for tipping the nibs of fountain pens, and for similar purposes.

The most important compound of osmium is osmium tetroxide,  $\text{OsO}_4$  (the so-called "osmic acid"), which, although a solid, has the property of boiling at about  $100^\circ\text{C}$ . and giving off exceedingly irritating vapours which are very poisonous. It is the heaviest metal known.

**Otto's Alloy.**—A speculum or mirror metal. Composition: copper, 68.5%; tin, 31.5%.

**Oxidised Silver.**—This is not a true alloy, but consists merely of silver to which a dull surface finish has been given by chemical means.

## P

**"P.2" Alloy.**—A light aluminium alloy developed by The Birmingham Aluminium Casting Co., Ltd. Used for pressure die castings. Contains: copper, 3%; nickel, 1.75%; magnesium, 0.5%; iron, 2%; silicon, 4%; manganese, 0.5%, the remainder being aluminium.

**Packfong.**—A nickel or German silver.

**Palau.**—A palladium-gold alloy. Composition: gold, 20%; palladium, 80%. It is used as a substitute for the more expensive platinum. Laboratory crucibles are sometimes made of it.

(The name "Palau" is a contraction of "Palladium" and "Aurum" (gold).)

**Palladium.**—Metallic element. Chemical symbol, Pd; At. No. 46; At. Wt. 106; M.P.  $1549^\circ\text{C}$ .; B.P.  $2820^\circ\text{C}$ .; Sp. Grav. 11.4; Sp. Ht. 0.0714; Coef. Exp. 0.00001176.

Like all the platinum metals, of which group it is a member, palladium is found in the metallic state alloyed with platinum and its allied metals. Discovered by W. H. Wollaston in 1803-4, and named by him after the minor planet *Pallas* which had been discovered about the same time.

Palladium is a greyish-white metal which is fairly ductile and malleable. It is softer than platinum and has a lower melting point than the latter. Although scarcer than platinum, it is commercially cheaper because it is not in such great demand. Palladium is the only one of the platinum metals which will dissolve in a single acid, it being soluble in hot concentrated nitric acid. Palladium possesses the remarkable property of being able to absorb or occlude a large quantity of hydrogen gas, one part of metallic palladium at red heat being able to absorb about 900 parts of hydrogen. Several applications have been made of this interesting property.

Alloyed with gold, palladium whitens the metal, several of the "white golds" being gold-palladium alloys.

Palladium also alloys with lead, tin, nickel, copper, antimony and bismuth. Salts of palladium have been used in photography in the production of "palladio-type" permanent prints.

**Palladium Bearing Metal.**—An extremely hard alloy, sometimes used in watches instead of jewelled bearings. Composition: palladium, 24 parts; gold, 72 parts; silver, 44 parts; copper, 92 parts.

**Palladium Gold.**—(See White Gold.)

**Palladium Leaf.**—Very thin palladium foil which is sometimes used for "silvering" purposes. Palladium leaf can be produced in thicknesses of as little as 1/200,000 of an inch.

**Pantal.**—A German aluminium alloy containing titanium as a hardening element. Composition: silicon 0.7%; magnesium, 1.4%; manganese, 0.9%; titanium, 0.2%—remainder aluminium. Tensile strength, 18,000 lb. per square inch. Brinell hardness, 40.

**Parisian Alloy.**—Also known as Parisian Metal. An imitation silver. Composition: copper, 69%; nickel, 19.5%; zinc, 6.5%; cadmium, 5%.

**Parkerising.**—(See Bonderising.)

**Partinium.**—An alloy introduced in France some years ago for bicycle and motor-car fittings. It is light and strong. Average composition: aluminium, 88.5%; copper, 7.4%; zinc, 1.7%; silicon, 1.1%; iron, 1.3%.

**Passive Iron.**—Iron which has been immersed in concentrated nitric acid. It does not dissolve when subsequently immersed in dilute acid. The cause of this "passivity" of iron is unknown, but is thought to be due to the formation of an extremely thin film of surface oxide.

Bismuth, cobalt, chromium and nickel are other metals which exhibit this phenomenon of "passivity" to a lesser degree.

**"Patenting."**—(See Wire Patenting.)

**Patronite.**—A mineral from which vanadium is produced. Chemical symbol,  $V_2S_5 + nS$ .

**Pearlite.**—The "pearly constituent of steel." It is a mixture of cementite (an iron carbide) and pure iron, and, under the microscope, it has an appearance resembling mother of pearl. Annealed steels contain a large proportion of pearlite.

**Pencil Alloy.**—A metallic composition which leaves a heavy mark when drawn across paper and can therefore be used as a pencil core. Since it contains mercury, it is an amalgam. Composition: lead, 70 parts; bismuth, 90 parts; mercury, 8 parts.

**Pentlandite.**—A nickel mineral ore occurring in the Sudbury deposit. (See Garnierite.)

## PERALUMAN

**Peraluman.**—A Swiss aluminium alloy. Similar to **Hydro-nalum** (which see).

**Permalloy.**—Name given to a class of nickel-iron alloys originally developed in 1921 by the Western Electric Company, of America. The original "Permalloy" contained 78.5% nickel and 21.5% iron, all impurities being kept down to a minimum. After suitable heat-treatment, such alloys develop a remarkable magnetic permeability, and much use has been made of them in radio and electrical work on this account.

**Permanite.**—A cobalt steel containing about 17% of cobalt. Used particularly for the making of permanent magnets.

**Permant.**—A low expansion nickel-iron alloy containing about 36% of nickel. Its expansion is about  $1\frac{1}{2}$  millionths per degree Centigrade. Used in horology, instrument and other work.

**Permax.**—A nickel-iron alloy chiefly used for its magnetic properties. For example, under magnetic fields varying from 200 gauss to 1 gauss the coercive force changes only from 0.48 to 0.45.

**Perminvar.**—Name given to a group of iron-nickel-cobalt alloys used for electrical purposes. They have negligible hysteresis losses and they possess constant magnetic permeability at low field strengths. Typical composition: nickel, 45% ; cobalt, 25% ; iron, 30%.

**Petzite.**—Mineral containing gold and tellurium.

**Pewter.**—Name given to a number of lead-tin alloys which have been put to extensive uses since the Middle Ages. Some pewters contain small amounts of copper and/or antimony. The so-called "leadless pewters" made nowadays are usually unalloyed tin.

**Pholin's Alloy.**—A silver-like alloy containing a trace of mercury. Composition: bismuth, 19.23% ; tin, 76.9% ; copper, 3.84%, plus mercury, a trace.

**Phosphor-Bronze.**—A copper-tin alloy containing a small percentage (about 0.10) of phosphorus. It is a hard, fine-grained, yellow-coloured metal having great toughness and a high tensile strength.

"Low Tin Bronzes" contain from 3.5% to 5% of tin, whilst "High Tin Bronzes" contain from 4.5% to 7% tin. For special purposes, phosphor-bronze containing up to 9% of tin is available.

**Phosphor-Tin.**—This is really a tin phosphide, containing about 21% of phosphorus. Although it is silvery-white in colour, it is not metallic. Made by heating tin with phosphorus out of contact with air.

**Pig Iron.**—This is a crude form of iron nowadays machine cast. It is of varied composition, a typical grade of pig iron containing, in addition to iron, about 4% of carbon and 2% of

silicon together with smaller amounts of sulphur, manganese and phosphorus. Some of this carbon is combined with the iron, some of it is merely dissolved in the iron. If much of the carbon is combined, the metal has a light appearance and is known as White Pig Iron. If the majority of the carbon is merely dissolved or "free," the metal appears grey and is known as "Grey Pig Iron." Intermediate types are known as "Mottled Pig Iron."

Pig iron is not malleable or ductile.

Pig or cast iron forms the starting point for the manufacture of wrought iron and the various steels. It has a relatively low melting point (1200° C.). It is now sold, not by colour, but on the basis of analysis. Various kinds of pig iron include foundry, basic, charcoal, malleable, bessemer, and silvery. The latter is a blast furnace product made from siliceous ores, coal, coke, and limestone. It contains from 5% to 17% silicon, up to 4% manganese, and is low in carbon, phosphorus, and sulphur. Its name is derived from its characteristic silvery fracture, and it is widely used in the cupola, converter, and open hearth in the production of grey iron, malleable, and steel. (See **Wrought Iron.**)

**Pigs.**—(See **Sow.**)

**Pimple Metal.**—Name given to impure copper containing copper oxide.

**Pin bar.**—Pin bar is mild steel that is supplied carburised and refined. The size ordered is delivered with a grinding allowance, and consequently it is only necessary to cut the material to length and to harden and grind it. It thus saves time in that it can be treated as if it were ordinary hardening steel. The suppliers were W. T. Flather & Co.

**Pinchbeck.**—An imitation gold which was first manufactured by Christopher Pinchbeck, an eighteenth-century London watchmaker. Average composition: copper, 5 parts; zinc, 1 part. It has a dark golden colour and it does not readily tarnish. It is malleable and can be rolled out into thin plates. It has been used to an enormous extent in cheap jewellery.

**Pinholes.**—Minute air-holes in a metallic casting.

**Pireks.**—Trade name for a series of heat- and acid-resisting alloys, largely used in furnace construction. Made by Darwins, Ltd.

**Pitho.**—A low alloy non-distorting tool steel.

**Plaster Amalgam.**—An amalgam for coating plaster objects. Composition: tin, 1 part; bismuth, 1 part; mercury, 1 part. (Add the mercury to the molten metals.) For use, rub up the amalgam with a little egg-white, and then brush it over the plaster surface like paint or varnish.

## PLASTIC BRONZE

**Plastic Bronze.**—(See **Copper-Lead Alloys.**)

**Plate Pewter.**—A variety of pewter used for making teapots, plates and other tableware. Composition: tin, 79 parts; antimony, 7 parts; bismuth, 2 parts; copper, 2 parts. It takes a high polish and does not contain lead.

**Platiniridium.**—A naturally-occurring alloy of platinum and iridium, containing from 30% to 75% of iridium.

**Platinised Asbestos.**—Platinum powder deposited on asbestos, and employed in such form on account of its chemical activity. Prepared by soaking good-quality asbestos fibre in a solution of platinum chloride and then strongly heating it.

**Platinite.**—A nickel-iron alloy containing from 42% to 50% of nickel. Its coefficient of expansion is similar to that of glass, on account of which it is used in the form of wire for embedding in or passing through glass, thus providing an absolutely gas-tight glass-metal joint in electric lamps, radio valves, etc. It replaces the much more costly platinum which was formerly used for this purpose. Is often employed in the copper-coated state, which provides a still more secure bond between glass and metal.

**Platino.**—An alloy containing about 11% platinum and 89% gold. Used in chemical apparatus designed to resist alkaline fusion attack.

**Platinoid.**—A nickel or German silver alloy, largely used in electrical work on account of its high resistance. Also used in jewellery. Composition: copper, 60 parts; nickel, 14 parts; zinc, 24 parts; tungsten, 1-2 parts.

**Platinor.**—Name given to a number of alloys containing platinum, copper, silver, zinc and nickel in varying proportions. They have a golden-yellow colour.

**Platinum.**—Metallic element. Chemical symbol, Pt; At. No. 78; At. Wt. 195; M.P. 1755° C.; B.P. 2650° C.; Sp. Grav. 21.45; Sp. Ht. 0.03243; Coef. Exp. 0.00000886.

The best-known and most useful member of a famous family of "noble" metals. Occurs always in the metallic state alloyed with palladium, iridium and allied metals. Its costliness is occasioned not only by its natural scarcity but, also, by the operations of a "ring" of producers.

The metal was first recognised as an individual one by R. Watson in 1750. Previously, it had been known to South American Spaniards under the name of "platina," this term being the diminutive of the Spanish *plata*, meaning "silver." "Platina," therefore, was the "little silver." It was considered as a dross in silver, and at one time was actually thrown away by order of the Spanish Government in order to prevent its being used for adulterating gold. The scientific use of platinum dates from comparatively recent times. It is a

whitish metal, with a greyish tinge. It is malleable and ductile and will take a very high polish. On account of its coefficient of expansion being about the same as that of glass, platinum wires were long used for sealing in the glass of electrical devices. Substitute wires are now used for this purpose.

Platinum is used in the jewellery, electrical and scientific-instrument trades on account of its well-known permanent qualities. It is one of the most useful of metals. Its salts are used in photography in the "platinotype" process. Platinum salts are highly poisonous. Platinum itself alloys with a large number of metals.

**Platinum Alloy.**—A thickly-fluid lead-grey metallic mass. It is made by grinding spongy platinum with hot mercury.

**Platinum-Black.**—A velvety black powder consisting of finely-divided metallic platinum which is highly chemically active, particularly when freshly made. Prepared by adding a reducing agent, such as formalin, to a solution of platinum chloride.

Platinum-Black will absorb as much as 100 times its volume of oxygen or hydrogen.

**Platinum-Bronze.**—Name given to a group of alloys containing from 0.5% to 10% of platinum. They polish well and retain their lustre for a long time, whilst they are relatively inexpensive. A typical platinum-bronze composition is : platinum, 0.9% ; nickel, 90% ; tin, 9%.

**Platinum Lead.**—(See **Birmingham Platinum.**)

**Platinum Metals.**—A family of six metals, having similar properties and appearances to platinum. These are : ruthenium, rhodium, palladium, osmium, iridium, platinum. The first three are sometimes termed the "Light Platinum Metals" and the latter three the "Heavy Platinum Metals" on account of their differences in specific gravity.

**Platinum Sponge.**—A black, spongy form of metallic platinum obtained by heating ammonium chloroplatinate. Is highly chemically reactive.

Platinum sponge (or "Spongy Platinum") will cause a mixture of coal gas and air to ignite, this being the principle of many of the automatic gas-lighters.

**Platnam.**—A nickel-copper alloy of high corrosion resistance. Introduced by Messrs. J. Hopkinson & Co. Composition : nickel, 54% ; copper, 33% ; tin, 13%.

**Plumber's Solder.**—M.P. 260° C. Composition : lead, 2 parts ; tin, 1 part. The alloy is also known as "Coarse Solder." Between about 250° C. and 180° C. this solder remains in a semi-fluid or pasty condition, thus allowing a plumber to "wipe" a joint in a satisfactory manner.

**Pocket.**—Metallurgical term denoting a cavity in a mass of metal.

## POLITAL

**Polital.**—A German aluminium alloy. Composition : silicon, 1.1% ; magnesium, 0.75% ; manganese, 0.4% ; nickel, 0.15% —remainder aluminium. Brinell hardness, 30–40. Tensile strength (heat-treated) 17,000 lb. per square inch.

**Polonium.**—One of the decomposition products of radium and identical with Lord Rutherford's "Radium F."

It was detected in pitchblende by Madam Curie in 1898 just previous to her discovery of radium, and was so named by her in honour of her native country, Poland.

It is doubtful whether metallic polonium has ever been isolated, since it has only a short "life."

**Polybasite.**—Mineral containing silver. Chemical symbol,  $9(\text{Ag}_2\text{Cu})\text{S}(\text{SbAs})_2\text{S}_3$ .

**Polydoroff.**—A powder iron used for the manufacture of telephone repeater coils and wireless inductances. (See **Ferrocarr.**)

**Potassium.**—Metallic element. Chemical symbol, K (from the Latin *Kalium* = potash). At. No. 19 ; At. Wt. 39 ; M.P. 65.5° C. ; B.P. 757° C. ; Sp. Grav. 0.859 ; Sp. Ht. 0.1728 ; Coef. Exp. 0.000084 ; Elec. Cond. at 0° C. (Mercury = 1) 11.23.

Occurrence : Potassium salts are contained in plant ashes. Hence the name "pot-ash." They are contained in seawater and in a large number of varying minerals. Chief source of supply is Carnallite, a double chloride of potassium and magnesium,  $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ .

Metallic potassium was first prepared by Sir Humphry Davy in October, 1807, by means of the electrolysis of caustic potash. It is a silvery-white, lustrous metal which tarnishes instantly on exposure to air or oxygen, becoming coated with a film of oxide. Potassium metal is lighter than water and floats upon that liquid. It interacts with water, producing hydrogen gas (which takes fire owing to the heat of the reaction) and potassium hydroxide (caustic potash). Potassium, like sodium, can be cut with a knife, and it is sufficiently soft to be moulded by the fingers. When deposited in very thin films on glass, potassium appears violet.

Potassium metal has been used in the production of certain types of photo-electric cells, and, alloyed with sodium, its companion metal, it has been used in place of mercury in certain types of high-temperature thermometers.

In consequence of its rapid oxidation when exposed to air, potassium must always be kept under an oil such as naphtha. Potassium is slightly radio-active.

**Potassium Amalgam.**—An amalgam of potassium and mercury. May be of varying composition, becoming more and more solid as the amount of potassium is increased. Is a mercury-like liquid or a shining, pasty, metallic mass, which evolves hydro-

gen when plunged into water. Like sodium amalgam, it forms a compound,  $K_2Hg$ , after being heated to  $440^{\circ} C.$  for some time, this crystalline material frequently being spontaneously inflammable. (See **Sodium Amalgam.**)

**Pot Metal.**—Name sometimes given to a number of copper-lead casting alloys. Typical composition: copper, 88%; lead, 12%.

**Potosi Silver.**—Nickel or German silver.

**Powder Metallurgy.**—The process of making metallic articles by moulding powdered metal, and in this respect the methods of working it are similar to ordinary plastics.

In the manufacture of bearings powder metallurgy is found of value, for bronze bearings are best made from porous metal, especially in cases where it is not possible to provide continuous lubrication. A successful bearing alloy must contain a mixture of hard and soft particles. In the case of porous bearings the hard particle or matrix is a 90/10 bronze, and the soft particle is a hole or pore. Thus a continuous lubricating film always exists over the whole surface of the bearing, even before rotation of the shaft commences. Some manufacturers add a small percentage of powdered graphite, and others a small percentage of a lubricant to facilitate the pressing operation. High-speed mechanically-operated presses of the eccentric cam-operated or rotary type are used for manufacture, and they provide for production up to 500 pieces per minute, as well as automatic feeds of the correct weight of powder, pressing and automatic ejection.

Metal powders possess little ability to flow under pressure in a die. In a pressing of any depth it is usually desirable to press from both ends simultaneously, and this procedure is usually combined with a movable core rod in the case of bushing dies. Upon ejection the parts must be heat treated or sintered.

By powder metallurgy articles can be made exactly to size and shape without machining. During sintering dimensional changes occur, either growth or shrinkage—generally the former,—and the close control of these means a careful control over the quality of the powder, the composition of the mixture, the pressing operation, and the exact time and temperature cycle in sintering. After sintering, bearings made by this process are impregnated with lubricating oil, either  $110^{\circ} C.$  for 10 to 15 minutes, or at a lower temperature in a vacuum chamber. Finally, the bearings are sized to the necessary tolerances in a mechanical operated sizing press.

The familiar hard metal carbide tool, such as Wimet, Ardaloy, Cutanit, Tecometal, etc., is made entirely by powder metallurgy. Although compositions vary to some extent, most of them consist of tungsten carbide with or without a proportion

## POWDER METALLURGY

of titanium carbide, together with a proportion of binding or auxiliary metal (from 3 to 13%) which is usually cobalt, with or without proportion, of nickel or iron. In America, tantalum carbide is being used to a considerable extent. Tungsten carbide can be melted and cast, but it is brittle and has little ability to withstand the shocks it will receive on use on a lathe. Powder metallurgy enables the hardness of the hard metal particles to combine with the toughness of the bonding metal to produce a tool possessing the optimum qualities of both.

For a tungsten carbide tool bonded with cobalt the powders involve preparation of pure tungsten oxide from the ore and reducing it in stages by heating in hydrogen until a pure tungsten powder of the right grain size is obtained. It is then mixed with carbon powder and heated in hydrogen in a carbon tube at approximately 1,500° C.

Iron and copper powders for use in powder metallurgy are produced by reduction of the oxide by the use of hydrogen, coal gas or by electrolysis. Tin, lead, and the light metal powders, such as aluminum powders, are produced by atomizing. In preparing either the straight metal powder or the alloy powders, the purity of the metals and the shape of the metal particles should be carefully watched. Only clean surfaces of the metal particles will give a continuous cohesive surface in compression, thus assuring subsequent strength in the finished part.

The shape of the particles of metal powder should be angular, not globular, as globular powders do not compress well, though for certain applications, such as filters, globular powders may be used advantageously. Angular powders will deform under pressure, interlock, and give strength of cohesion to the compact sufficient to permit handling of the compacted piece even before sintering. Where clean surfaces of the powder particles are assured, the heat created by pressure and friction is sufficient to create a molecular weld.

Metal powders are available of practically all known metals, but in addition a number of pre-alloyed powders such as brass powder, bronze powder, and ferro-alloy powders, have been produced. Some of the age-hardening alloys, however, are best created during the process of sintering. The age-hardened powders are generally too hard to compact easily, and even when they do, the resulting part is generally brittle and of low physical properties. If the compact is formed from copper, aluminum, magnesium, or in the case of ferrous metals, iron, nickel, or chrome, the metals can be annealed before compression and the softness of the powder allows excellent compression conditions. The alloys are then formed during the sintering operation.

It is important not to mix light and heavy metals as they

will tend to segregate and will not compact into a homogeneous mixture. Even if the mixing or blending of the different metals takes place immediately prior to their use, the mixing must continue from a few hours to 24 hours or longer to insure absolutely even distribution. Pressures to form a compact vary from a few tons to 160 tons per square inch (about 25 tons per sq. cm.). By high pressure high physical properties are obtained in iron parts. The selection of what pressure is desired is governed entirely by the physicals expected in the finished part, how close such part is to come to the full density of the metal or alloy, or how much porosity is expected.

A large application for the metal powders has been in making so-called oil-less or self-oiling bushings and bearings. Here porosities of 5, 10, and even 25% have been demanded, and the pressure varies according to the porosity expected. Porosity does not depend entirely upon the shape of the particles or the pressure exerted, but can be created by mixing volatile salts, sawdust, etc., with the powders. During sintering these materials are volatilized, thus making spaces held by this material available for oil adsorption, and also creating channels which allow the compact to absorb oil through capillary attraction. After the compact has been compressed, it is essential to sinter it. Sintering in air is rarely employed due to the danger of oxidation. Hydrogen is applied for most parts made from the more expensive metals. For everyday commercial operation, controlled atmosphere such as cracked ammonia or one of the controlled gases produced in special equipment is used. Optimum temperatures and periods of sintering for individual metals and compositions have been established by many tests.

**Praseodymium.**—Metallic element. Chemical symbol, Pr; At. No. 59; At. Wt. 140.5; M.P. 940° C.; Sp. Grav. 6.4754.

Occurs in very small amounts in the commoner rare-earth minerals, such as Cerite. Discovered in 1885 by Auer von Welsbach, who named it from its resemblance to neodymium (which was discovered at the same time) and from the characteristic green colour of its salts (Greek *prasinos*, leek-green).

Comparatively little is known about praseodymium. It is a greyish metal, having a very pronounced yellowish hue. It is similar in properties to neodymium. No alloys of praseodymium have been made. (See **Neodymium**.)

**Primary Zinc.**—An American term, denoting zinc which has been produced by direct smelting from its ore.

**Prince's Metal.**—(See **Mannheim Gold**.)

**Pro-Platinum.**—A platinum-like alloy containing silver and a small quantity of gold. Composition: nickel, 72.00%; silver, 23.57%; bismuth, 3.72%; gold, 0.71%.

## PROTOACTINIUM

**Protoactinium.**—Radio-active metallic element. Chemical symbol, Pa ; At. No. 91 ; At. Wt. 39.1. Practically nothing is known of the properties of this element. It was discovered by Hahn and is the parent substance of actinium ; hence its name. It is considered to be somewhat similar to tantalum. It exists in pitchblende.

**Proustite.**—Mineral containing silver. Chemical symbol,  $3\text{Ag}_2\text{S} \cdot \text{As}_2\text{S}_3$ .

**Pucherite.**—Bismuth vanadate.

**Puddled Steel.**

**Pyrargyrite.**—Mineral containing silver. Chemical symbol,  $3\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$ .

**Pyrite.**—Native disulphide of iron ( $\text{FeS}_2$ ), crystallising in isometric forms, especially in cubes and pyritohedra. One of the forms of iron pyrites. Copper pyrites.

**Pyrolusite.**—a manganese mineral. Chemical symbol,  $\text{MnO}_2$ .

**Pyromorphite.**—A resinous, variously coloured lead chlorophosphate ( $\text{Pb}_5\text{P}_3\text{O}_{12}\text{Cl}$ ) ; green lead ore.

**Pyrophoric Alloys.**—Name given to certain alloys which possess the property of throwing off sparks when scratched or struck. Such alloys usually contain the metal cerium, since all the metals of the cerium group possess this pyrophoric property to some extent. Such alloys are mainly used for the "flints" of automatic lighters and other sparking devices. A well-known alloy of this type contains cerium plus about 30% of iron. Besides, the use of cerium-iron alloys, metals containing tin, lead, zinc, cadmium, silicon, etc., have been patented for pyrophoric uses. Pyrophoric alloys find application in connection with "tracer" bullets, and in devices for showing up the flight-path of shells. (See **Kunheim** and **Mischmetal**.)

**Pyroxene.**—A species including a large variety of minerals, all bisilicates of lime with one or more other bases, usually magnesia and iron oxide, but also manganese, zinc, potash and soda pyroxine ( $\text{RS}_1\text{O}_3$ ).

## Q

**Quartz.**—A widely diffused mineral, crystallising in hexagonal prisms ; in a pure form consisting of silica or silicon dioxide ( $\text{SiO}_2$ ) but varying greatly in colour and lustre. Specific gravity, 2.65.

**Quartzite.**—An extremely compact granular rock, consisting mainly of quartz.

**Quartzoid.**—A crystal having the form of a double six-sided pyramid.

**Quaternary Steels.**—Steels containing three special alloying

metals, as, for example, nickel-chromium-manganese steel. Such steels are sometimes styled "complex steels."

**Queen's Metal.**—A variety of Britannia metal. The proportions of its ingredients vary widely within the following limits: tin (50-75%), antimony (16-8%), bismuth (16-8%), lead (16-8%). The metal is softer than Britannia metal, but is sometimes used for the same ornamental purposes.

**Quenched Steel.**—Steel which has been heated to a definite temperature and then suddenly cooled by "quenching" or immersion in water or oil. Such steel thereby becomes hardened.

**Quicksilver.**—A common name for **Mercury** (which see).

## R

**Radiometal.**—A nickel-iron alloy developed by The Telegraph Construction and Maintenance Company, Ltd. Used in electrical and radio work on account of its magnetic permeability.

**Radium.**—Metallic element. Chemical symbol, Ra; At. No. 88; At. Wt. 226.5; M.P. 700° C. approx.

Chief ore: Pitchblende,  $U_3O_8$ . Discovered in this ore in 1898 by Madam S. Curie, who obtained about a quarter of a gram of radium salt from one ton of the ore. Called "radium" by Madam Curie in reference to its powerful radiating properties.

Metallic radium is a rarity of rarities, since all the "radium" used in hospitals and scientific work constitutes the various salts of this element. Radium, however, is a white metal which rapidly turns black in air owing to the formation of the nitride. Like all its compounds it is always at a temperature a few degrees higher than that of its surroundings. The metal is a soft one and can be cut with a knife. It is self-luminous. It dissolves in water and most acids. Forms an amalgam with mercury.

Metallic radium throws off from itself three types of "rays," viz.—*alpha rays*, which consist of helium atoms, *beta rays*, which are negatively-charged electrons, and *gamma rays*, which are similar to X-rays. The metal, in ejecting these "rays," very slowly disrupts itself, gradually changing into lead. It has been calculated that one-half of any given specimen of radium will have become disrupted and changed after the elapse of 2,000 years. "Radium A," "Radium B," "Radium C," "Radium D," and "Radium E" are all consecutive decomposition products of the parent radium.

## RAMET

**Ramet.**—One of the American brands of cemented carbides.  
(See **Cemented Carbides.**)

**Rare-Earth Metals.**—A family of metals derived from certain scarce minerals known as the “rare earths.” They are the following: cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutecium, neodymium, praseodymium, samarium, scandium, terbium, thulium, ytterbium (neoytterbium), yttrium.

It should be noted that this group of metals does not contain all the “rare” metals, but only those specifically derived from the “rare earths.” Metallic radium, for instance, which is excessively rare, is not a member of the rare-earth group of metals.

**Razor Steel.**—A carbon steel containing 1.5% approx. of carbon. It is apt to be brittle and if at all over-heated, its properties are rendered useless. Used for razors, surgical instruments, small tools, etc.

**Realgar.**—One of the arsenical minerals. Chemical symbol,  $\text{As}_2\text{S}_2$ .

**Recalescence.**—A peculiar behaviour of iron and other magnetic metals when cooling from white heat, the metal reaching the temperature of dull red-heat and suddenly brightening up again, after which it cools off in the normal manner. The phenomenon has also been termed “after glow.” (From the Latin *re*, again; *caescere*, to become hot.)

**Red Brass.**—(See **Steam Metal.**)

**Red Gold.**—A gold-copper alloy. Composition: gold, 75%; copper, 25%. A “dark-red” gold contains: gold, 50%; copper, 50%.

“**Red Short.**”—(See “**Short.**”)

**Regulus of Antimony.**—This is the metallic antimony of commerce. It is an ancient term which has survived, “regulus” being the Latin for “a little king,” and thus, in this usage, implying that the metal, being impure, has not attained its full maturity and powers.

**Regulus of Venus.**—An ancient term denoting a beautiful crystalline alloy of a very rare violet colour obtained by melting together equal parts of copper and antimony. (From the Latin *regulus*, a little king.)

**Reith's Alloy.**—An alloy prepared by Herr Reith, of Bockenheim, Germany, and said to be resistant to acid and alkaline solutions. Composition: copper, 74.5 parts; tin, 11.6 parts; lead, 9 parts; antimony, 4.9 parts.

This alloy is a bronze, with the addition of lead and antimony.

**Relative Malleability.**—(See **Malleability.**)

**Resistance to Impact.**—(See **Izod Test.**)

**Retz Alloy.**—An acid and alkali-resisting alloy. Composition: copper, 15 parts; tin, 2.34 parts; lead, 1.82 parts; antimony, 1 part.

**Rezistal.**—Name given to a group of iron-chromium-nickel-silicon alloys of American origin.

**Rhenium.**—Metallic element. Chemical symbol, Re; At. No. 75; At. Wt. 186; M.P. 3200° C. approx.; Sp. Grav. 21.40; Sp. Ht. 0.0346.

Discovered in 1925 by Noddack and Tacke, along with the element masurium. Occurs in columbite and in certain platinum ores. Also in molybdenum ores.

Rhenium, although a newly-discovered element, is now commercially obtainable in metallic form. It is a greyish metal similar, in many respects, to tungsten and platinum. Although the metal is, as yet, too scarce to be employed industrially, it has been tried for electroplating purposes and has been found to give a hard, bright and acid-resisting deposit. Probably much more will be heard of this new metallic element in the future.

**Rheotan.**—A copper-zinc-manganese alloy, used for electrical resistance purposes. Composition: copper, 84%; zinc, 4%; manganese, 12%.

**Rhodio-Platinum.**—An alloy sometimes used for high-temperature thermojunctions in electrical thermometers. Composition: rhodium, 10%; platinum, 90%.

**Rhodium.**—Metallic element. Chemical symbol, Rh; At. No. 45; At. Wt. 103; M.P. 1950° C.; B.P. 2750° C.; Sp. Grav. 12.1; Sp. Ht. 0.05803; Coef. Exp. 0.0000085.

Occurs in the metallic state alloyed with platinum and its related metals to the extent of from 0.5% to 5% of rhodium. Discovered in 1804 by W. H. Wollaston and named by him from the Greek *rodon*, a rose, in respect of the rose-red colour of its salts.

Rhodium, being one of the platinum metals, is a costly metal and has been little used in the "mass" condition. It is silvery-white in colour, being, in respect of whiteness, second only to silver. For this reason, rhodium is now plated on to the reflectors of motor car and bicycle headlamps, since it is absolutely untarnishable. It is also plated on to silver articles in order to prevent them from tarnishing.

Rhodium is even more acid-resistant than platinum, for it is not appreciably soluble in any acid or mixture of acids. It is a much lighter metal than platinum. It forms alloys with all the platinum metals, some of which may, in the future, attain positions of importance. If only the metal were cheaper, rhodium would completely supersede silver, nickel and chromium as plating metals, for it is practically

## RHODOCHROSITE

as white and as lustrous as silver, besides being completely non-oxidisable and untarnishable.

**Rhodochrosite.**—A manganese mineral. Chemical symbol,  $MnCO_3$ .

**Rhodonite.**—A manganese mineral. Chemical symbol,  $MnSiO_3$ .

**Rhometal.**—A nickel-iron alloy of high magnetic permeability. Used for electrical work.

**Rhotanium.**—A rhodium-gold alloy. Sometimes used for laboratory crucible making.

**Richardson's Alloy.**—A speculum or mirror metal. Composition : copper, 65.3% ; tin, 30% ; zinc, 0.7% ; arsenic, 2% ; silver, 2%.

**Rolled Gold.**—This consists of an extremely thin veneer of gold affixed to a sheet of base metal. The two are rolled out to any required dimensions, thus giving a film of metallic gold on the surface of the inferior metal.

**Ronia Metal.**—Name sometimes given to brass containing small amounts of cobalt, manganese and phosphorus.

**Roscoelite.**—A mineral from which vanadium is produced. Chemical composition,  $HgK_2(MgFe)(AlV)_4(SiO_3)_2$ .

**Roséin.**—A jewellery alloy of silvery hue. Composition : nickel, 40 parts ; silver, 10 parts ; aluminium, 30 parts ; tin, 10 parts.

**Rose's Metal.**—A well-known fusible alloy originally devised by Sir T. Kirke Rose. M.P.  $93.75^\circ C$ . Composition : bismuth, 2 parts ; lead, 1 part ; tin, 1 part.

**R.R. Alloys.**—A series of high-strength heat-treatable aluminium alloys developed by Rolls-Royce, Ltd. A typical alloy of this type (R.R.56) is the following :

Copper	.	.	.	.	.	.	2.0%
Nickel	.	.	.	.	.	.	1.3%
Magnesium	.	.	.	.	.	.	0.8%
Iron	.	.	.	.	.	.	1.4%
Titanium	.	.	.	.	.	.	0.1%
Silicon	.	.	.	.	.	.	0.7%
Aluminium	.	.	.	.	.	.	93.7%

The above typical R.R. alloy has a M.P. of  $635^\circ C$ . and a Sp. Grav. of 2.75. All such alloys are readily worked and modified in properties, and they are much used for aircraft work, Air Ministry specifications, and, also, in automobile engineering. After their invention by Rolls Royce, Ltd., they were subsequently developed by High Duty Alloys, Ltd.

The original alloy of this type was the "R.R. 50."

**Rubidium.**—Metallic element. Chemical symbol, Rb ; At. No. 37 ; At. Wt. 85 ; M.P.  $39^\circ C$ . ; B.P.  $696^\circ C$ . ; Sp. Grav. 1.525.

## RUTILE

Discovered in certain mineral waters by Bunsen and Kirchhoff in 1860, and named by them "rubidium" from the Latin *rubidus*, red, in significance of the red spectrum lines which are characteristic of this element.

Rubidium is a white, lustrous metal having an extremely faint yellow tinge. It is as soft as wax. Exposed to the air, rubidium metal oxidises with such rapidity that it eventually takes fire spontaneously. When heated *in vacuo*, it forms a blue vapour. The metal decomposes water, with the evolution of hydrogen (which takes fire) and the formation of rubidium hydroxide.

In all its properties, rubidium metal is very similar to potassium. Next to caesium, rubidium is the most electro-positive metal known. In order to prevent it from oxidising itself away (and catching fire spontaneously), metallic rubidium must be kept under naphtha or some other oil in a manner similar to potassium and sodium.

Rubidium is slightly radio-active.

**Ruolz Alloys.**—A series of cheap jewellery alloys manufactured some years ago by a M. Ruolz, of Paris. Average composition: silver, 20-30%; nickel, 25-30%; copper, 35-50%.

**Ruolz's Silver.**—(See **Argent-Ruolz.**)

**Rustless Iron.**—This is really rustless (or stainless) steel containing about 0.1% of carbon. It can be tempered and given a maximum tensile strength of from 30 to 70 tons per square inch according to the type of heat-treatment which it has been afforded. Because it is malleable, it has a wider range of application for the production of forgings, pressings and stampings than have the normal stainless or rustless steels. (See **Ascoloy.**)

**Rustless Steel.**—(See **Stainless Steel.**)

**Ruthenium.**—Metallic element. Chemical symbol, Ru; At. No. 44; At. Wt. 101.5; M.P. 2450° C.; B.P. 2780° C.; Sp. Grav. 12.26; Sp. Ht. 0.0611; Coef. Exp. 0.00000963.

Occurs in the metallic state alloyed with platinum and its related metals. Is always a constituent of *osmiridium*. Discovered in 1845 by A. Claus and given the name "ruthenium" from *Ruthenia*, a former name for Russia.

Ruthenium is a white, lustrous metal. It is hard but brittle. The metal in the mass is insoluble in all acids, but dissolves in hot aqua regia (mixture of nitric and hydrochloric acids) when in the powder form. Ruthenium, mainly in view of its scarcity, has no commercial uses. It alloys with all the platinum metals.

**Rutile.**—A titanium-bearing mineral.

## S

**Sacrificial Metal.**—A rather fanciful name given to a metal which, as it were, is sacrificed in order to ensure the safety of another. A good example of a sacrificial metal is the zinc coating of galvanised iron. Although the zinc surface layer of the iron sheeting is slowly dissolved away by weathering, no rusting of the iron takes place so long as any zinc remains.

**Saddlery Brass.**—(See **Aluminised Yellow Brass.**)

**Samarium.**—Metallic element. Chemical symbol, Sm; At. No. 62; At. Wt. 150; M.P. 1300°–1400° C.; Sp. Grav. 7.7.

Discovered in 1879 by Lecoq de Boisbaudran in residues obtained from the rare mineral *samarskite*, and thereupon named "samarium." It is doubtful whether metallic samarium has ever been obtained in an entirely pure form. It constitutes a member of the cerium family of rare metals. It is the hardest of the cerium metals and has a greyish appearance. It alloys with all the cerium metals.

**Samarskite.**—A tantalum ore, also containing uranium. It is radio active. (See **Fergusonite**.)

**Satco Metal.**—A white bearing metal which has been used on American railroads. Composition: tin, 1.0%; calcium, 0.5%; mercury, 0.25%; aluminium, 0.05%; magnesium, 0.04%; potassium, 0.04%; lithium, 0.04%—remainder lead. It is said to have a Brinell hardness number of 24–27.

**Scandium.**—Metallic element. Chemical symbol, Sc; At. No. 21; At. Wt. 44; discovered in 1879 by Nilson in *euxenite* and *gadolinite*, rare minerals occurring in Scandinavia, and named by him "Scandium" in honour of the latter countries.

Scandium is a greyish-white metal, not unlike beryllium. It is little known at the present day, but, in view of the fact that scandium compounds occur (in small amounts) in a large number of minerals, there is a possibility that the metal may become commoner at some future time.

**Scheelite.**—One of the tungsten minerals. Chemical symbol,  $\text{Ca}(\text{WO}_4)_2$ .

**Scoop Metallising.**—A process in which a wire or strip of zinc is fed into an oxy-hydrogen air blast of such intense power that the metal is melted and projected in the form of a fine spray on to a metallic object held in its path. In this way, a fine spray of zinc is obtained and a zinc coating of any required thickness given to an object so treated.

**Scleron.**—A German aluminium alloy containing lithium. Composition: silicon, 0.5%; copper, 3%; zinc, 12%; manganese, 0.2%; lithium, 0.1%—remainder aluminium. Brinell hardness, 150. Tensile strength, 60,000 lb. per square inch.

**Selenide.**—A compound of selenium with an element or a radical.  
**Selenium.**—(See “ Metallic ” Selenium.)

**Selenium Copper.**—This, a new introduction, consists of copper containing up to 0.5% of selenium. Has the advantage of easy machinability.

**Self-Hardening Steels.**—Name given to certain varieties of alloy steels, such as tungsten steels, which do not require quenching (i.e. sudden cooling) to harden them after forging.

**Semi-metal.**—Another name for **Metalloid** (which see).

**Shadke.**—A Japanese alloy consisting of copper with from 1% to 10% of gold. Articles made from this alloy are “ pickled ” in a solution of copper sulphate, alum and verdigris until they attain a bluish-black coloration.

**Shaku-do.**—(See **Chinese Bronze**.)

**Shear Steel.**—This is blister steel (which see) after it has been cut up, reheated, welded and then hammered or rolled.

If, after welding, the steel is doubled on itself, reheated and again welded, it is known as “ double-shear steel.”

**Sheet Metal Alloy.**—An alloy which has a silvery-white colour and which can easily be rolled into thin sheets. Used for lining tea-chests, metallic wrapping papers, etc. Average composition : tin, 35 parts ; lead, 250 parts ; copper, 2.5 parts ; zinc, 0.5 parts.

**Sheffield Plate.**—Name applied to a veneer of silver on copper, brass or other base metal. The invention of Thomas Boulsover, a Sheffield cutler, in 1742. Originally made by binding a silver plate by means of iron wire to a thicker and slightly larger copper or brass plate, coating the edges with a borax paste, and then sweating the two plates together in a red-hot furnace. The composite sheet thus obtained, was subsequently rolled down to any requisite thickness.

**Sherardising.**—A method of coating iron with zinc by surrounding it with powdered zinc mixed with some zinc oxide and heating it for some time to a temperature between 250° and 400° C. A thin, uniform and firmly-adherent coating of zinc is thus imparted to the iron. Finished iron articles can conveniently be treated in this manner.

**Shibu-ichi.**—(See **Chinese Bronze**.)

“ **Short.**”—A term used in practical metallurgy to denote the lack of malleability and toughness of a metal. The presence of a trace of phosphorus in iron renders the metal “ short ” in the cold, or “ cold short.” Such metal lacks malleability when cold, but regains it at red heat.

Similarly, other impurities render a metal “ short ” at red heat—“ red short.” Sulphur in iron makes the metal “ red short.” Such metal is not very malleable at red heat, but it can be worked fairly well below that temperature.

## SHOT METAL

**Shot Metal.**—This is merely lead containing 9 parts of arsenic per 1,000. It is employed for the manufacture of lead shot by allowing drops of the molten metal to fall from a considerable height into water. It is found that the presence of a small quantity of arsenic in the lead, by lowering its melting point, enables it to form more perfectly spherical droplets when falling. Also that the arsenic makes the lead harder.

**Shot Nickel.**—Commercial name sometimes applied to nickel in the form of granules or small cubes.

**Shrapnel Brass.**—Used for ammunition and ordnance, etc. Composition : copper, 67% ; zinc, 33%.

**Siachu.**—(See Japanese Brass.)

**Sickened Mercury.**—Mercury which has attained a state of very fine division so that its fine globules do not unite together. The condition is the same as **Floured Mercury** (which see).

**Sideraphite.**—A silver-white alloy having the composition : iron, 63 parts ; nickel, 23 parts ; tungsten, 4 parts ; aluminium, 5 parts ; copper, 5 parts. It is very malleable and ductile. It is fairly acid-resisting and is cheaper than most of the white metals or nickel silvers. It is, however, little seen nowadays.

**Siemens Steel.**—(See Open-hearth Steels.)

**Sigmalium.**—A Belgian aluminium alloy. Composition : silicon, 0·8% ; copper, 3·8% ; manganese, 0·7%—remainder aluminium. Tensile strength, 60,000 lb. per square inch.

**“ Silal ” Cast Iron.**—A type of cast iron containing from 5·5% to 7% of silicon.

**Silical.**—A Scandinavian aluminium alloy. Similar to **Silumin** (which see).

**Silico-Manganese Steel.**—A type of steel sometimes used for the manufacture of springs. It contains, on an average, 0·5% carbon, 1·5–2% silicon, and 1·5–2% manganese.

**Silicon.**—Silicon in common steels is only a few hundredths of 1%, but occasionally, especially in steel for castings, it may reach 0·5%. Higher silicon contents puts the product in the class of special steels. Silicon is a deoxidising agent, and for that reason is an aid in the production of sound castings. It probably exists in steel in the form of a silicide of iron (FeSi).

**Silicon Brass.**—Generic term applied to alloys of copper and zinc which contain, also, some silicon. In addition, they frequently contain a little tin, a typical “ silicon brass ” having the composition : copper, 65–85% ; zinc, 20% ; silicon, 2–6% ; tin, 0·1–3·0%.

These alloys were originally developed in Germany about 1930, and they have considerable strength together with reasonable ductility. They are readily cast and are sometimes used for heavy-duty bearing metals.

**Silicon Bronze.**—Used as a high-strength casting alloy. Is mainly a copper-silicon alloy containing small amounts of metals such as manganese, zinc and iron. Typical compositions are :

- (a) copper, 95% ; silicon, 4% ; manganese, 1% ;
- (b) copper, 88% ; silicon, 5% ; iron, 5% ; zinc, 2%.

These have tensile strengths of approximately 25 tons per square inch.

**Silicon-Chromium Steel.**—A steel largely used for the exhaust valves of internal-combustion engines on account of its resistance of heat and pitting. Contains about 3% of silicon and 11% of chromium.

**Silicon Monel.**—A variety of monel having a higher silicon content than normal. It is used for casting work and may be heat-treated.

**Silicon Steel.**—Name given to a class of steels containing silicon in amounts up to 15%. Silicon alloyed with steel gives a metal of great soundness and toughness, since it is a powerful deoxidiser and removes gases and oxides from steel, thus rendering the metal free from "blebs" and blowholes.

Steels containing up to 2% of silicon are sound internally and elastic. With 4% silicon, the steel becomes much stiffer, whilst steels having a silicon content of 5% and upwards are not forgeable.

Silicon steel has a good tensile strength but a rather low resistance to impact. With higher silicon contents the steel becomes acid-resisting, and is employed a great deal on this account.

**Silky Fracture.**—Term referring to a type of metal fracture in which the broken metal surfaces present a brilliant silky and lustrous appearance. Metals, as, for example, copper and steel, which present this type of fracture are tough and strong, and usually malleable.

**Silmalec.**—An aluminium alloy containing magnesium (0.6%) and silicon (1%), the two latter ingredients acting as hardeners. Can be heat-treated. Tensile strength about 22 tons per square inch.

**Silumin.**—An aluminium-silicon alloy. Composition : aluminium, 88% ; silicon, 12%. It may also, at times, contain a little magnesium.

**Silver.**—Metallic element. Chemical symbol, Ag (from the Latin *Argentum*). At. No. 47 ; At. Wt. 108 ; M.P. 960° C. ; 1950° C. ; Sp. Grav. 10.5 ; Sp. Ht. 0.0557 ; Coef. Exp. 0.00001921 ; Therm. Cond. 100 (Copper = 73.6) ; Elec. Cond. at 0° C. (Mercury = 1) 100.

Chief ores : Argentite or Silver glance,  $\text{Ag}_2\text{S}$  ; Pyrargyrite or Ruby Silver ore,  $\text{Ag}_3\text{SbS}_3$  ; Proustite,  $\text{Ag}_3\text{AsS}_3$  ; Horn

## SILVER BELL METAL

Silver,  $\text{AgCl}$ . Also occurs in lead ore, such as argentiferous galena, and in the free metallic state.

Silver has been known from very early times, being mentioned in the Old Testament. The alchemists referred to the metal as "Luna" and gave it the mystic symbol of the crescent moon.

Silver is a white, lustrous metal, being the whitest and most reflective of all metals. It is, also, the best-known conductor of heat and electricity. The pure metal is malleable and ductile. Very thin films of silver appear green when viewed by transmitted light, whilst the vapour of boiling silver is also green. When molten, silver has the curious property of absorbing up to 22 times its own volume of oxygen, which, for the most part, it gives up again when cooling. Sometimes this ejection of absorbed oxygen by cooling molten silver is forcible, and the phenomenon is known as the "spitting of silver." In dry, pure air, silver preserves its lustre fairly well, but in air charged with traces of sulphur compounds it rapidly tarnishes owing to the formation of a surface film of silver sulphide.

Silver finds its chief uses in the making of coins and in the jewellery, plating and photographic industries. The metal forms numerous alloys.

**Silver Bell Metal.**—An alloy used for making small bells. It is white in colour and gives a silver-clear tone. Composition: copper, 41.5%; tin, 58.5%.

**Silver Bronze.**—A resistance alloy having a greater electrical resistance than German silver. Composition: manganese, 18 parts; aluminium, 1.2 parts; silicon, 5 parts; zinc, 13 parts; copper, 67.5 parts.

**Silver Steel.**—A carbon steel containing 1.0–1.2% carbon. It should be heat-treated in the following manner: Forge at  $950/1,000^\circ\text{ C}$ . To water-harden, heat very gradually to a dull red ( $760$ – $780^\circ\text{ C}$ .) and place vertically into water, moving the steel slowly until cold.

To oil-harden, heat slowly to a red heat ( $820$ – $850^\circ\text{ C}$ .), plunge in oil, linseed or olive preferred, and move rapidly until cold. Overheating does not increase the hardness to any appreciable extent. The best heat is the lowest at which the steel becomes glass hard. Little tempering is then required.

**Silverite.**—An imitation silver composed of German or nickel silver.

**Silveroid.**—An imitation silver. It comprises an alloy of copper, nickel, tin, zinc and lead in many different proportions.

**Silver Solder.**—These alloys vary enormously in composition.

The best one is probably: silver, 4 parts: copper, 1 part.

Another contains: silver, 2 parts; brass, 1 part.

**Silver Tree.**—Name given to a cluster of fern-like silver crystals obtained by suspending a strip of zinc in a solution of silver nitrate.

**Similor.**—(See **Mannheim Gold.**)

**Singer's Amalgam.**—An electric amalgam used in frictional machines, etc. Composition: tin, 1 part; zinc, 2 parts; mercury,  $3\frac{1}{2}$ –6 parts.

**Sintering.**—A process originally produced to agglomerate fine ores to ensure that the product was more suitable for the blast furnace. Before its introduction fine ores were either briquetted for blast furnace use or smelted directly in a reverberatory furnace. Apart from agglomerating the material, sintering removes part of the sulphur, thus relieving the roasting furnaces of part of their burden. Sintered ore is porous and is thus more easily smelted than the comparatively dense briquetted ore; thus furnace capacities are increased. (See **Powder Metallurgy.**)

**Skutterudite.**—A cobalt-bearing mineral.

**Smaltite.**—A cobalt-bearing mineral. Chemical symbol,  $\text{CoAs}_2$ .

**Smithsonite.**—One of the zinc oxide ores. Chemical symbol,  $\text{ZnCO}_3$ , 52·14% Zn.

**Sodium.**—Metallic element. Chemical symbol, Na (from the Latin *Natrium*, soda). At. No. 11; At. Wt. 23; M.P. 97·6° C.; B.P. 877·5° C.; Sp. Grav. 0·9723; Sp. Ht. 0·293; Coef. Exp. 0·000072; Therm. Cond. (Silver = 100) 36·5; Elec. Cond. at 0° C. (Mercury = 1) 18·3.

Sodium is one of the “alkali” metals, being the metallic constituent of soda and common salt. It was first isolated in the metallic state by Sir Humphry Davy in October, 1807 shortly after he had isolated its closely-related metal, potassium. Sodium possesses all the properties of potassium, but is slightly heavier and slightly less chemically reactive. Thus, sodium, when thrown on to water, vigorously interacts with that liquid, with the evolution of hydrogen and the formation of sodium hydroxide (caustic soda) in solution, but the energy of this reaction is rather less than the energy of the reaction between potassium and water, so that the hydrogen evolved in the sodium reaction does not take fire like it does in the case of potassium.

Like potassium metal, metallic sodium is a white, lustrous metal, which is soft enough to be cut with a knife. Exposed to air, it oxidises with great rapidity, so that it is necessary to preserve it under an oil such as naphtha. In thin layers on glass, sodium appears yellowish-brown. It alloys with potassium and forms amalgams with mercury.

Metallic sodium is used in chemical synthetical operations and in the manufacture of sodium peroxide, a constituent of

## SODIUM AMALGAM

washing powders. It is also used in the manufacture of sodium cyanide, which is an important industrial chemical. (See Potassium.)

**Sodium Amalgam.**—An amalgam of sodium and mercury made by dissolving clean metallic sodium in mercury. May be of varying composition, becoming more and more solid as the percentage of sodium in the mercury is increased. Is a mercury-like liquid, or a bright, shining, metallic mass which evolves hydrogen in a steady stream when acted upon by water. On account of this fact, the amalgam has many uses in chemistry.

When carefully heated to 440° C. and retained at that temperature for some time, sodium amalgam forms a crystalline compound of the supposed formula,  $\text{Na}_3\text{Hg}$ . This is often spontaneously inflammable. Potassium amalgam forms a similar compound. (See Potassium Amalgam.)

**Soft Bronze.**—(See Gunmetal.)

**Softness.**—(See Hardness.)

**Soft Steel.**—(See Steel.)

**Sol.**—An alchemical name for gold.

**Solder.**—Name given to a number of lead-tin alloys used for the uniting of electrical wires, pipes and for other purposes. The name comes from the Latin *solidare*, to make solid. (See Fine Solder, Plumber's Solder, Common Solder, etc.)

**Soldering.**—This may be defined as the process of effecting a union between two metals by means of the use of an alloy or metal of lower melting point and differing from the metals to be united together. (From the Latin *solidare*, to make solid.)

**Sollit's Alloy.**—A speculum or mirror metal. Takes a very high reflecting polish. Composition: copper, 64.6% ; tin, 31.3% ; zinc, 4.1%.

**Sorbite.**—A more or less ill-defined mixture of cementite (iron carbide) and pure iron (ferrite). Named after the famous H. C. Sorby, metallurgist, of Sheffield, the "Father of Modern Metallurgy." Tempered steels consist mainly of sorbite.

**Sorel's Alloys.**—Copper-zinc-iron alloys. Typical composition: copper, 10% ; zinc, 80% ; iron, 10%. They are very hard and cast well. Used in statuette work, etc.

**Sow.**—This is the main channel along which the molten iron flows from the blast furnace. Its lateral branches are termed "the pigs," and in these the molten iron solidifies to cast or "pig" iron.

**Sparking Alloys.**—(See Pyrophoric Alloys.)

**Special Steels.**—(See Alloy Steels.)

**Specific Density.**—(See Specific Gravity.)

**Specific Gravity.**—The number which expresses the weight of a metal (or other body) compared with that of an equal volume of water at a standard temperature and pressure, the weight of water being taken as unity (1). It is sometimes referred to as the Density or Specific Density of the metal.

The Specific Gravity is sometimes increased by mechanical treatment of the metal, such as rolling, hammering, stamping, since all such treatments tend to close the pores of the metal and thus to increase its compactness. The Specific Gravity of a metal may be regarded as a measure of its degree of inner compactness. The greater the Specific Gravity of a metal the heavier the latter is. Lithium (Sp. Grav. = 0.534) has the smallest Specific Gravity of all metals; osmium (Sp. Grav. = 22.47) the greatest. With the exception of bismuth, all metals have a smaller Specific Gravity when molten than they have in the solid state.

**Specific Heat.**—This expresses the capacity for heat which a metal (or other substance) possesses compared with that possessed by an equal weight of water. The term also denotes the amount of heat required to raise the temperature of one gram of a metal (or other substance) one degree Centigrade.

Since metals vary in Specific Heats, it follows that different metals require different amounts of heat to raise equal weights of them through a temperature of 1° C. The higher the Specific Heat of a metal, the more heat it absorbs and the more heat it gives out on cooling.

**Speculum Metal.**—A white metal which takes a high polish and which has been used for making telescope and other types of mirrors. It is composed of copper, 2 parts; tin, 1 part. Is seldom made nowadays.

**Speise.**—In lead smelting arsenic if present combines with some of the iron cobalt and nickel to form arsenides, which form a product known as Speise.

**Spelter.**—The commercial name for crude zinc. The name is derived from the Dutch *spiauter*.

**Spence's Metal.**—Strictly speaking, this is not a metallic material. It consists of a solution of certain metallic sulphides, as, for instance, those of iron, zinc or lead, in molten sulphur. The "metal" forms a hard, tenacious, metallic-looking mass of Specific Gravity 3.37 to 3.7. It melts at about 320° F. and expands on cooling. Is useful at times for making air- and gas-tight joints in laboratory apparatus, etc.

**Sperrylite.**—A mineral containing arsenic and platinum. Chemical symbol, PtAs<sub>3</sub>.

**Sphalerite.**—The important sulphide mineral of zinc, sometimes known as Blende. It is also known as Resin Jack or

## SPIEGELEISEN

Black Jack. Its composition is Zns (60% Zn, 33% S). This mineral is the principal source of zinc.

**Spiegeleisen.**—A white iron containing manganese; largely used in the manufacture of steel. It is very hard and brittle; its specific gravity is 7.6 approx. When more than about 20% of manganese is present in the alloy it is called ferromanganese (which see). It is used to recarburize and deoxidise the molten metal.

The name is derived from the German *Spiegel-eisen* (mirror-iron), because of the brilliancy of its fractured surfaces.

**Spongy Iron.** (See **Iron, Spongy.**)

**Spongy Platinum.** (See **Platinum Sponge.**)

**Stainless Steel.**—Name given to a variety of chrome steel containing between 11% and 15% of chromium and about 0.45% of carbon. Small amounts of silicon, nickel, and/or manganese are, also, sometimes contained in these steels. Stainless steels are hard and are generally manufactured in the electric furnace. They do not take the temper of ordinary carbon steels, but they are practically unaffected by atmospheric oxygen, moisture, fruit and vegetable acids. By raising the chromium content, increased chemical resistance may be conferred upon these steels.

Ordinary stainless steel has a tensile strength of about 70 tons per square inch. These steels are sometimes known as "Rustless steels."

**Stalloy.**—A silicon steel of high magnetic permeability. Used for transformer cores, etc.

**Standard Gold.**—The British gold coinage used to contain 91.66% of gold and 8.33% of copper, this constituting "standard" or "sterling" gold.

**Standard Silver.**—Contains 92.5% silver, 7.5% copper. Standard silver is said to have a "fineness" of 925, since 1,000 parts of the metal contain 925 parts of pure silver. For many years, this was the standard of English silver currency and silver plate as regulated by law. Hence the expressions, *Sterling silver* and *English standard silver*.

**Stannite.**—A mineral found in conjunction with Cassiterite, the important mineral of tin. Chemical symbol,  $FeCu_2SnS_4$ .

**Star Antimony.**—(See **Star Metal.**)

**Star Metal.**—Commercial term for refined antimony. Also "Star Antimony." Contains a minimum of 99.5% antimony.

**Statuary Bronze.**—Many of these bronzes are used. They vary in colour from pale yellow to a reddish yellow, and have the following limiting compositions: copper, 65-80%; zinc, 11-31%; tin, 2.5-4.5%.

**Statue Bronze.**—Name given to a large group of copper-tin-zinc alloys of varied proportions, the copper content varying

from 87% to 65%. Typical composition: copper, 85% ; zinc, 11% ; tin, 4%.

**Staybrite.**—A chrome-nickel steel containing about 18% of chromium and 8% of nickel.

**Steam Metal.**—Sometimes called "Red Brass" on account of its heightened colour. Used in locomotive and steam engine parts, etc. Many steam metals of varying composition are known. The following is the composition of standard steam metal: copper, 87% ; zinc, 3% ; tin, 7% ; lead, 3%.

**Steel.**—A form of iron containing less carbon than pig or cast iron but considerably more than wrought iron. Ordinary steel contains from 0.5% to 1.5% of carbon, and it was to such metals that the term "steel" was originally applied. The term, however, has now been extended to include "Mild Steel," which may contain from 0.1% to 0.5% of carbon, and, also, to the so-called "alloy" or "special" steels which contain other metals, such as nickel, chromium, etc.

Ordinary steel contains small percentages of sulphur and phosphorus, but these impurities are usually kept down to a limiting maximum of 0.05%.

"Hard" steel contains 0.9% approx. carbon. "Soft" steel contains 0.1% approx. carbon, whilst "Medium" steel contains about 0.4% carbon.

The properties of the different steels are very varied and cannot possibly be set down here. In general, however, steel may be given different characteristics by various forms of heat and mechanical treatment, thus making it one of the most useful and valuable alloys known to civilisation.

**Steel Bronze.**—Composition: copper, 60 parts ; ferro-manganese (containing 70-80% manganese), 40 parts ; zinc, 15 parts.

**Steel-faced Iron.**—A bi-metallic product in which the component metals are iron or mild steel and tool steel.

**Stellite.**—Commercial alloy of tungsten, which does not contain iron. It is composed of tungsten, chromium and cobalt in varying proportions. An average composition consisting of cobalt 55%, molybdenum 5%, chromium 15% and tungsten 25%. It can be used for making cutting tools, for it retains an extremely hard edge, and actually becomes tougher and more enduring as it becomes hotter. It is resistant to the action of nitric acid.

**Stephanite.**—A mineral containing silver. Chemical symbol,  $5\text{Ag}_2\text{S} \cdot \text{Sb}_2\text{S}_3$ .

**Stephenson's Alloy.**—A white, anti-friction bearing metal. Composition: tin, 31% ; copper, 19% ; zinc, 19% ; iron, 31%.

**Stereotype Metal.**—One of the many type metals. Typical

## STERLINE

composition: lead, 112 parts; tin, 3 parts; antimony, 18 parts.

**Sterline.**—An imitation silver type of metal. Composition: copper, 68.5%; nickel, 17.88%; zinc, 13–14%; iron, 0.5–0.75%.

**Sterling Gold.**—(See Standard Gold.)

**Sterling Silver.**—(See Standard Silver.)

**Sterro Metal.**—Consists of: copper, 60%; zinc, 38%; iron 2%. Occasionally used as a ship-sheathing alloy to prevent corrosion by seawater.

**Stibnite.**—An important antimony mineral. Chemical symbol,  $Sb_2S_3$ . Some  $Sb_2O_3$  is also found. Chiefly in the upper layers of Stibnite deposit. It is readily fusible and may be liquated from rich ore in a comparatively pure state.

**Stream Tin.**—Name given to tin derived from ores found in alluvial deposits, having been washed down by streams or rivers on to lower-lying lands. Foreign tin is mostly of this variety. (See **Lode Tin.**)

**Strontium.**—Metallic element. Chemical symbol, Sr; At. No. 38; At. Wt. 87.5; M.P.  $800^{\circ}\text{C}.$ ; B.P.  $1000^{\circ}\text{C}.$ ; Sp. Grav. 2.542.

One of the “alkaline earth” metals. Strontium metal was first isolated by Sir Humphry Davy in 1808. Its name is derived from the mineral *strontianite*, which was first discovered near the Scotch village of Strontian, in Argyllshire, in 1787.

Pure strontium is a silvery-white metal which oxidises rapidly in contact with air and which decomposes water at ordinary temperatures with the evolution of hydrogen and the formation of strontium hydroxide. Hence, the metal must be preserved below the surface of oil.

The metal has few, if any, uses, but some of its compounds are of use, notably those which are employed in firework-making on account of the fact that they give a crimson colouration to flames.

**Sun Bronze.**—A tenacious, ductile and hard alloy which melts at approximately the same temperature as copper. Composition: copper, 30–50%; aluminium, 10%; cobalt, 40–60%.

**Super-Duralumin.**—Composition: copper, 4.0%; magnesium, 0.5%; manganese, 0.5%; silicon, 1.25%—remainder aluminium. Tensile strength about 35 tons per square inch.

Super-duralumin is the hardest of all the duralumin alloys.

**Supra Piston Alloy.**—Composition: copper, 5%; silicon, 20%; manganese, 2%; iron, 0.7%—remainder aluminium. Tensile strength, 21,000 lb. per square inch. Brinell hardness, about 120.

**Sylvanite.**—Mineral containing gold and tellurium. Chemical symbol,  $(AuAg)Te_2$ .

## T

**Talmi Gold.**—Also known as “Abyssinian gold.” Contains : copper, 86.4% ; zinc, 11.2% ; tin, 1.4%. Better grades contain 0.5% or 1% of gold. Used for cheap jewellery, since it has the appearance of gold.

**Tandem Metal.**—(See **Mangolia Metal.**)

**Tantalum.**—Metallic element. Chemical symbol, Ta ; At. No. 73 ; At. Wt. 181 ; M.P. 2950° C. ; Sp. Grav. 16.5.

Originally discovered by C. Hatchett (1801) in some chromium minerals from Connecticut, U.S.A., and called by him “Columbium,” in honour of America. A year later (1802) A. G. Ekeberg discovered the same element in some Finnish minerals and called it “Tantalum” (from *Tantalus*, of Greek mythology, who withheld many tortures) in allusion to the “tantalising” difficulties which he experienced in separating its compounds.

At a later date, the name “Columbium” was applied to the element, Niobium, “Tantalum” being finally given to the element discovered by Hatchett and Ekeberg.

Tantalum is an iron-grey metal having a lustrous surface. It is hard and difficultly fusible and from this metal were made the first metal-filament electric lamps during the period 1905-11. Sheet tantalum can now be obtained, but the metal is too rare to be of any large-scale service.

Its chief ore is Tantalite,  $\text{Fe}(\text{TaO}_3)_2$ .

**Tealite.**—A mineral found in small quantities in association with Cassiterite, the important mineral of tin. Chemical symbol,  $\text{PbSnS}_2$ .

**Tecometal.**—One of the commercial brands of cemented or sintered carbides. (See **Tungsten Carbides.**)

**Telectal.**—A silicon-lithium-aluminium alloy of German origin. Composition : silicon, 1.5% ; lithium, 0.3%—remainder aluminium.

Has a Brinell hardness of 100 and a tensile strength of 40,000 lb. per square inch.

**Telluride.**—Name given to a compound of tellurium with another metal or a non-metal, as, for example, copper telluride, lead telluride, etc.

**Tellurium.**—Metallic element. Chemical symbol, Te ; At. No. 52 ; At. Wt. 127 ; M.P. 453° C. ; B.P. 1390° C. ; Sp. Grav. 5.93-6.4 ; Sp. Ht. 0.0475 ; Coef. Exp. 0.00001675.

Is found in a few rare minerals, such as Tellurite,  $\text{TeO}_3$ . Some specimens of iron pyrites used in the manufacture of sulphuric acid contain traces of tellurium, and from this source the tellurium of commerce is usually obtained.

## TELLURIUM BRONZE

Tellurium was discovered by Muller von Reichenstein in 1782, and given its name by M. H. Klaproth in 1798, from the Latin *tellus*, the earth.

Tellurium is a silvery-grey material. It is a poor conductor of heat and electricity, and, by some, is considered to be a *metalloid* rather than a true metal. Tellurium is slightly light-sensitive, its electrical conductivity increasing slightly when light falls upon it. Tellurium is very brittle, and when the molten element is slowly cooled, it forms rhombohedral crystals. Heated in a sealed tube with hydrogen, it forms brilliant prismatic crystals. When heated in air, tellurium burns with a blue flame.

Tellurium forms well-defined compounds with other metals, such compounds being known as *tellurides*. Bismuth telluride,  $\text{Bi}_2\text{Te}_3$ , is a typical example of these compounds. Such compounds may be regarded as definite alloys of tellurium with other metals.

**Tellurium Bronze.**—A copper-tin alloy containing up to 1% of tellurium. Typical composition: copper, 97.8%; tin, 1.5%; tellurium, 0.95%. Has been introduced on account of its easy machinability.

**Tempered Lead.**—(See *Noheet*.)

**Tempering.**—Referring to carbon steel, this denotes the re-heating of the metal whereby it gradually loses its hardness to a degree depending upon the temperature to which it is heated.

**Tenacity.**—The property possessed by a metal or alloy of resisting forces tending to tear it asunder. It depends upon the degree of cohesion of the molecules of metal. (See **Tensile Strength**.)

**Tenörite.**—(See *Melaconite*.)

**Tensile Strength.**—A measure of a metal's resistance to rupture by the application of a tensile stress or stretching force. The tensile strength of a metal is usually expressed in tons per square inch or sometimes in lb. per square inch. Various machines for estimating the tensile strength of metals are now used.

The term "tenacity" is sometimes employed to denote tensile strength.

(From the Latin *tendere*, to stretch.)

**Terbium.**—Metallic element. Chemical symbol, Tb; At. No. 65; At. Wt. 159.

A rare metal occurring in the rare-earth mineral, yttria. It was discovered by C. G. Mosander in 1843 and named by him after Ytterby, in Sweden, where the mineral yttria is found. Terbium compounds were first obtained pure by Urbain in 1904. The metal is greyish. Traces of its com-

pounds in other oxides, such as aluminium oxide, set up an intense white luminescence, a property which promises to put terbium "on the map" at some future date.

**Ternary Alloy.**—An alloy containing three constituent metals.

**Ternary Steels.**—Steels which contain two special alloying metals, as, for example, chrome-nickel steel.

**Terne Coating.**—A process whereby steel articles are immersed in a molten bath of an alloy containing from 12% to 40% of tin, the remainder being lead. A protective coating is thereby acquired by the steel articles.

**Terne Plate.**—An inferior quality of tinplate coated with a lead-tin alloy instead of with pure tin as in the case of tinplate proper. It is frequently used for the insides of packing-cases.  
(From the French *terne*, dull.)

**Tetrahedrite.**—A complex mineral frequently containing sulphides of Cu, Fe, Zn, Ag, Hg, Sb and As.

**Thallium.**—Metallic element. Chemical symbol, Tl; At. No. 81; At. Wt. 204; M.P. 302° C.; B.P. 1462° C.; Sp. Grav. 11.86; Sp. Ht. 0.0335; Coef. Exp. 0.00003135; Elec. Cond. at 0° C. (Mercury = 1) 5.22.

Discovered in 1861 by Sir William Crookes in the selenium-bearing deposit from a sulphuric acid works, and named by him from the Greek *thallos*, a green twig, in allusion to the characteristic green lines which its compounds show in the spectroscope. Thallium occurs in Crooksite, a copper selenide, and, also, in certain zinc ores.

Thallium is a soft metal, very much resembling lead in physical properties. It is readily cut with a knife, and it marks paper when drawn across it. When a strip of zinc is placed in a solution of thallium sulphate, metallic thallium is deposited as a spongy mass. On exposure to air, the metal turns black, owing to the formation of black thallium oxide. The metal is soluble in dilute acids. It may be highly polished by rubbing under water. Thallium metal is very malleable and films of it of 1/15,000th inch thickness have been obtained. Thallium can be squeezed but not drawn into wire, and pieces of the metal can be welded together by pressure at ordinary temperatures.

Thallium readily alloys with metals such as antimony, bismuth, lead, cadmium and tin; also with harder metals such as aluminium, copper and magnesium. It forms amalgams with mercury.

**Thermal Conductivity.**—(See **Conductivity**.)

**Thermit Metal.**—(See **Everest Metal**.)

**Thermoflex Metal.**—A proprietary bimetal used for thermostatic purposes. It consists of a sheet of invar fixed to one of brass. (See **Bimetal**.)

## THORINUM

**Thorinum.**—An obsolete name for **Thorium** (which see).

**Thorium.**—Metallic element. Chemical symbol, Th; At. No. 90; At. Wt. 232; M.P. 1600° C.; Sp. Grav. 11.3; Sp. Ht. 0.02787.

Occurs in some rare minerals, such as Thorite. Discovered by J. J. Berzelius in 1818, and named by him from Thor, the Scandinavian thunder-god (to whom, also, we dedicate the *Thursday* of our week). Thorium compounds are now obtained from monazite sand.

Thorium is a metal which is very difficult to prepare in a state of purity. Small beads of it have been obtained resembling platinum, and the metal has also been made in the form of a black powder. The metal is resistant to acids, dissolving only in *aqua regia* (a mixture of nitric and hydrochloric acids). It has been obtained in the form of foil by ramming the powder thorium into copper tubes, beating them flat, and then dissolving away the copper with dilute nitric acid.

Next to uranium, thorium is the heaviest metal known. It is radio-active, although to a much less extent than radium. Thorium alloys with most metals. Its salts are used in the manufacture of gas-mantles. At a high temperature thorium metal burns in air with the production of a brilliant illumination.

**Thulium.**—Metallic element. Chemical symbol, Tm; At. No. 69; At. Wt. 168.5.

Thulium compounds were first isolated by P. T. Cleve in 1880, and the name "thulium" applied to them from *Thule*, an old name for Scandinavia.

It is doubtful whether metallic thulium, in even small amounts, has ever been prepared in anything like a state of purity. Practically nothing is known about the metal itself.

**Tiers-Argent.**—(Literally, this means "one-third silver.") An alloy consisting of silver, 33.33%; aluminium, 66.66%, formerly manufactured in Paris for making up into various cooking utensils.

**Tin.**—Metallic element. Chemical symbol, Sn (from the Latin *stannum*). At. No. 50; At. Wt. 118; M.P. 231° C.; B.P. 2200° C.; Sp. Grav. 5.8 to 7.3; Sp. Ht. 0.0559; Coef. Exp. 0.000020; Therm. Cond. (Silver = 100) 15.2; Elec. Cond. at 0° C. (Mercury = 1) 8.8.

Occurrence: chiefly in the mineral, tin-stone or cassiterite,  $\text{SnO}_2$ . Is often associated with tungsten, arsenic and copper. Tin has been known from very early times, such early supplies of tin having been obtained from Cornwall. For this reason, the British Isles were, in pre-Roman days, known as the "Cassiterides" or Tin Islands (Greek *cassiteros*, tin.)

Tin is a white, lustrous metal, having a faint blue tinge. The metal is not easily tarnished on exposure to air. The metal is harder than lead, but softer than zinc. It is very malleable, and it can be beaten into foil—tinfoil. It is also fairly ductile. At a temperature of 200° C. tin becomes so brittle that it can be ground into a fine powder. If a thin bar of tin be bent, it emits a crackling noise, known as the "tin cry." When cooled to a low temperature, tin crumbles into a powder—"grey tin," a fact which accounts for the so-called "disease" of tin. Tin can be obtained in crystalline form by melting a quantity of the metal and by pouring out the still liquid portion of the metal after the mass has been allowed partially to solidify. If a quantity of warm, dilute *aqua regia* (mixture of nitric and hydrochloric acids) be wiped over a piece of tin, it will take upon itself a surface crystalline structure. Tin is a highly important metal. It is used in tinning iron, and also in the preparation of numerous alloys, such as pewter, solder, etc.

**Tin Amalgam.**—A tin-mercury composition. Used at one time for coating mirrors. Prepared by the addition of mercury to a sheet of tinfoil which is pressed against the glass surface in order to squeeze out the excess of mercury.

**Tin Brass.**—Generic name given to alloys of copper and zinc which contain, also, some tin. For an example of a "tin brass," see **Corronium**.

"**Tin Cry.**"

**Tin-Free Bronzes.**—Name sometimes given to the copper-lead alloys, the lead being supposed to take the place of tin or zinc in the ordinary bronzes. They have been used as bearing metals for Diesel engines and in aircraft engines.

A typical alloy of this type contains; copper, 82%; lead, 18%. It has a Brinell hardness of 23 and a casting temperature of 1050° C.

**Tinned Iron.**—(See **Tinplate**.)

**Tin "Pest."**—(See **Grey Tin**.)

**Tinplate.**—Thin sheet iron which has been dipped into a bath of molten tin and thereby superficially coated with the latter metal. Used for the manufacture of tin cans and similar containers. The word "tin" used in its commonest sense usually refers to tinplate or "tinned iron."

**Tinsmith's Solder.**—Composition: lead, 40%; tin, 60%. Alternatively, lead, 33.3%; tin, 66.6%.

**Tissier's Metal.**—A red alloy, very hard. It may be considered to be a brass containing a high percentage of copper and hardened by arsenic. Was at one time used as a bearing metal. Composition: copper, 97 parts; zinc, 2 parts; arsenic, 1-2 parts. (This composition varies considerably.)

## TITANIUM

**Titanium.**—Metallic element. Chemical symbol, Ti ; At. No. 22 ; At. Wt. 48 ; M.P. 1795° C. ; B.P. 1800° C. ; Sp. Grav. 3.6 ; Sp. Ht. 0.1125.

Chief mineral ores : Rutile,  $TiO_2$  ; Anatase,  $TiO_2$  ; Brookite,  $TiO_2$ .

Discovered in Rutile by M. H. Klaproth in 1794, and named "Titanium" by him in classical allusion to the *Titians*, the giants of ancient mythology. Three years previously, the element had been discovered by W. McGregor in the mineral sand (*menachanite*) found at Menachan, in Cornwall, and named by him "Menachin."

Titanium is a steel-grey, hard metal closely related to the element silicon. The metal is very difficult to obtain in the pure state.

In the form of its alloys, titanium is well known, "ferrotitanium" being an alloy of iron with titanium. Even a trace of titanium added to steel increases the toughness of the metal. Titanium compounds are used in dyeing and in paint manufacture. Alloys of titanium with aluminium and beryllium are known. Titanium is not a rare element, since, in addition to its ores, it occurs in small quantities (about  $\frac{1}{2}\%$ ) in most clays, sands and granite rocks.

**Titanium Steel.**—First introduced in 1907, but even at the present day these steels are not much used. Titanium induces internal soundness in steel without over-hardening the metal. Owing, however, to the cost of titanium, true titanium steels are hardly a commercial proposition.

**Tobin Bronze.**—An alloy similar in properties and composition to **Delta Metal** (which see).

**Tombac Alloys.**—These are certain types of brasses containing more than 70% of copper which are manufactured for specialised uses. For example, a "tombac" brass comprising 74% copper and 26% zinc is frequently employed for the manufacture of brass wire for weaving into the gauzes of paper-making machines.

**Tonca's Alloy.**—An imitation silver. Composition : copper, 5 parts ; nickel, 4 parts ; tin, 1 part ; lead, 1 part ; iron, 1 part ; zinc, 1 part ; antimony, 1 part. It is very hard, somewhat brittle and difficult to melt. It is also not very ductile.

**Toucas' Metal.**—A complex jewellery alloy of the nickel-silver type, which takes a fine polish and has the lustre of platinum. Used for jewellery purposes. Composition : copper, 35.8 parts ; nickel, 28.7 parts ; antimony, 7.1 parts ; tin, 7.1 parts ; lead, 7.1 parts ; zinc, 7.1 parts ; iron, 7.1 parts.

**Toughness.**—Referring to metals, this may be defined as the property of resisting fracture by bending, twisting, hammering, etc.

**Tough Pitch Copper.**—(See **Marketable Copper.**)

**Tournay's Alloy.**—Composition : copper, 82.5% ; zinc, 17.5%.

A variety of brass which, having a golden appearance, is used for cheap jewellery, buttons, etc.

**Tourun-Leonard's Metal.**—An imitation silver, comprising bell metal admixed with tin. Composition : tin, 500 parts ; bell metal, 64 parts.

**Trabuk Metal.**—An imitation silver. Composition : tin, 87.5 parts ; nickel, 5.5 parts ; antimony, 5 parts ; bismuth, 5 parts.

**Triple Pewter.**—A variety of pewter used for small ornamental articles, toys, etc. Composition : tin, 79% ; antimony, 15% ; lead, 6%.

**Troostite.**—An ingredient which is formed in steel under certain conditions of slow cooling. "Troostitic" steel represents the most elastic condition of that metal.

**Tungsten.**—Metallic element. Chemical symbol, W (from *Wolfram*, an older name for the metal and also the name of its ore). At. No. 74 ; At. Wt. 184 ; M.P. 3267° C. approx. ; B.P. 3700° C. approx. ; Sp. Grav. 19.13 ; Sp. Ht. 0.035.

Occurrence : chiefly in the mineral, Wolfram,  $2\text{FeWO}_4 \cdot 3\text{MnWO}_4$ . Also in Scheelite,  $\text{PbWO}_4$ , and Wolfram ochre,  $\text{WO}_3$ .

The metal was first isolated by J. J. y Don Fausto d'Elhuyar in 1783, and was, for many years, known by the alternative names of Wolfram and Tungsten (from the Swedish *tung*, heavy ; *sten*, stone) in allusion to the weight of its ore, wolfram. The name "Wolfram" is nowadays only applied to the element in Germany, yet the chemical symbol, W, still persists.

Added in small amounts to steel, tungsten hardens and toughens the metal. Tungsten is nowadays universally employed for making the filaments of electric lamps, as it is almost infusible and is thus able to withstand the prolonged heating to whiteness. In many of its properties, tungsten is allied to molybdenum and chromium. Alloys of tungsten with aluminium, antimony, bismuth, cobalt, copper, lead and nickel have been obtained.

Of all the known metals, tungsten has the highest melting point.

**Tungsten Carbide.**—Obtained as a by-product from the manufacture of metallic tungsten, being derived from the slag resulting from this process. As an abrasive and as a material for tipping cutting tools it is finding increasing use in engineering.

The important characteristics of tungsten carbide are its hardness and its compressive strength. Therefore, metal

## TUNGSTEN NICKEL

cutting tools made of cemented or sintered carbides are now in general use in industry, chiefly because of the exceptionally high cutting speeds and long life which result from their use. They may be used for tools for cutting very hard materials or compositions which rapidly destroy other tools. It is the hardest metallic tool-material known, the harder grades being about three times as hard as hardened tool steel, whilst one of the grades of cemented carbide has the highest compressive strength of any known material, approximately 890,000 lb. per square inch. The sintered carbides are manufactured in a number of grades, and degrees of hardness and toughness, according to the material upon which they are to be used. Such carbides are now applied to various tools for turning, reaming, milling, etc. (See also **Powder Metallurgy**.)

**Tungsten Nickel.**—A nickel-tungsten alloy containing about 23% nickel and 73% tungsten. Used in the manufacture of nickel-tungsten steels.

## Tungsten Steel.

**Tungum.**—This is an alloy of 0.99% aluminium, 82.48% copper, 0.3% iron, 0.72% nickel, 14.6% zinc, 0.76% silicon. It is supplied in the cast, chill cast, or hard forged condition. Its mechanical properties are as follows :

Condition.	Tensile Strength. Lb. per sq. in.	Yield Point. Lb. p. sq. in.	Elongn. in 2 in.	Brinell Hardness.
Sand Cast .	46,600	23,000	51	98
Chill Cast .	49,300	22,000	67	112
Forged Hard .	114,700	104,800	11	218

It is used for compressor parts, pumps, centrifugal dryers, and chemical apparatus, and resists both acid corrosion and fatigue ; it is diamagnetic. Its specific resistance is four times that of copper. Electrical conductivity is quarter that of copper. Coefficient of expansion is 0.0000188 per deg. between 0-300 deg. Thermal conductivity is 0.184 at 100 deg. Fatigue limit is 12.5 tons per square inch in air and 11 tons per square inch in seawater for  $20 \times 10^6$  reversals.

**Tutanego.**—The name by which metallic zinc was known when, in the sixteenth century, it was imported into this country from China and the West Indies. The name was derived from the Persian *tutiya*, meaning "zinc."

**Tutania Metal.**—A tin-antimony-bismuth alloy, containing brass. Used for ornamental purposes. Composition : tin, 25% ; antimony, 25% ; bismuth, 25% ; brass (50 : 50) 25%. A variety of Britannia metal.

**Twoscore Steels.**—A group of Sheffield steels first produced in 1925. They are stainless and contain 17-20% chromium

and about 2% of nickel. They have been extensively used in the production of seaplanes and flying boats.

**Type Metal.**—Name given to a group of lead alloys containing from 13% to 30% of antimony, and sometimes tin or bismuth up to about 20%.

Typical composition : lead, 75% ; tin, 5% ; antimony, 20%.

All type metals expand slightly upon solidification. Hence they give fine and sharp impressions of their casting moulds, and, as such, are used for the production of printers' type.

**Typewriter Metal.**—A number of alloys named as above have been specially introduced for the purpose of providing the operating and type-bar levers of typewriters and similar machines. Such metals are stiff and strong, and can be bent a good deal without fracturing.

A typical "typewriter metal" contains : copper, 57% ; nickel, 20% ; aluminium, 3% ; zinc, 20%. These metals have a silvery-white colour and they give sharp, clean castings which are free from blowholes and pinholes.

**Tyseley Alloy.**—A zinc "die-casting" alloy. Composition : zinc, 78-93% ; copper, 0-3% ; magnesium, 0-1% ; aluminium, 4-22%.

## U

**Ubas.**—Trade name for a well-known brand of case-hardening steel.

**Ullmanite.**—A sulphide mineral containing nickel. Chemical symbol, NiSbS.

**Ulmal.**—A German aluminium alloy. Composition : magnesium, 10% ; silicon, 1% ; manganese, 0.5%—remainder aluminium. It has a Brinell hardness of about 90-100 and a tensile strength (after working) of 50,000 lb. per square inch.

**Ulminium.**—An aluminium alloy. The same as Duralumin.

**Ultralumin.**—A German aluminium alloy. Composition : copper, 4.7% ; manganese, 0.75% ; nickel, 0.2%—remainder aluminium. Tensile strength, about 55,000 lbs. per square inch.

**Uranium.**—Metallic element. Chemical symbol, U ; At. No. 92 ; At. Wt. 238.5 ; M.P. 1850° C. ; Sp. Grav. 18.685 ; Sp. Ht. 0.0276.

Chief ore : Pitchblende,  $UO_4$ ,  $UO_3$ .

Uranium was first detected in pitchblende by M. H. Klaproth in 1789, who named it in honour of Herschel's discovery of the planet, Uranus, in 1781. (Greek *ouranos*, the heavens.) The metal was first isolated by Péligot in 1840.

Uranium is a hard, lustrous, silver-white metal which is somewhat malleable, but which cannot be hammered into thin

## USEFUL METALS

plates. After long standing in air, the metal becomes covered with a steel-blue film of uranium oxide. The metal dissolves in dilute mineral acids.

Uranium is the "last of the elements," since it occupies the end position on the Table of Elements.

Uranium is radioactive, but has only about one-millionth of the ray-yielding power of radium.

Added to steel in small amounts, uranium toughens the metal. Its compounds have many varied uses in industry.

**Useful Metals.**—These are metals which have proved of most use in the history of civilisation. They are :

Iron	Molybdenum	Mercury
Gold	Zinc	Cobalt
Manganese	Antimony	Iridium
Nickel	Chromium	Lead
Vanadium	Sodium	Aluminium
Copper	Titanium	Magnesium
Silver	Tin	Tungsten
Bismuth	Platinum	Rhodium
Cadmium		

Naturally, the above list is an arbitrary one, and alloys are not included in it. Moreover, the rarer metals, such as zirconium, hafnium, caesium, beryllium and palladium, are now coming into an increasing use.

## V

**Vacuum-Cleaner Alloys.**—These aluminium alloys, which are employed for the housing of vacuum-cleaner motors, are similar to **Crankcase Alloys** (which see), but they often contain up to 10% of copper.

**Valve Metal.**—A type of steam metal or red brass used for valve cocks on steam engines, etc. Average composition : copper, 86% ; zinc, 8% ; tin, 3.5% ; lead, 2.5%.

**Vanadate.**—A salt of vanadic acid.

**Vanadinite.**—A mineral from which vanadium is produced. Chemical symbol,  $3\text{Pb}_3(\text{VO}_4)_2\text{PbCl}_2$  (lead chlor-vanadate).

**Vanadium.**—Metallic element. Chemical symbol, V ; At. No. 23 ; At. Wt. 51 ; M.P. 1720° C. : Sp. Grav. 5.5.

Occurrence : in a few rare minerals, mainly Vanadinite,  $3\text{Pb}_3(\text{VO}_4)_2\text{PbCl}_2$ . Also in very small amounts in certain iron ores, from which sources it is now usually obtained.

Metallic vanadium was first prepared by H. Roscoe—(Roscoelite) in 1867, although its existence had been discovered by Del Rio in 1801. In 1830, N. G. Sefström described a new mineral containing Del Rio's element, and he suggested for

the unknown metal contained in it the name "vanadium," from *Vanadis*, a Scandinavian goddess.

Vanadium is a silvery-white metal which is not easily tarnished in air. It has the curious property of attacking glass when heated in glass vessels, forming a compound with the silicon contained in the glass. Pure vanadium is without uses, but, as an alloying metal, it is of much import. Alloyed with steel, vanadium increases the hardness and malleability of the metal. The addition of  $\frac{1}{2}\%$  of vanadium to steel will increase the tensile strength of the steel from 7 to 13 tons per square inch. Vanadium is similar in chemical properties to columbium (niobium) and tantalum. Vanadium dissolves in hot acids. It is also attacked (like aluminium) by solutions of caustic soda and caustic potash.

**Vanadium Steel.**—Vanadium alloyed with steel in amounts ranging from 0.1% to 0.5%, increases the toughness and reliability of the metal. Up to 1% of vanadium may be alloyed with steel to increase its toughness.

In conjunction with chromium—as "Chrome-Vanadium steel"—it provides steels which, in view of their great toughness, are used for springs, tools, forgings and specialised types of engineering constructional work.

A typical chrome-vanadium steel contains 1% of chromium, 0.25% vanadium, 0.3% of carbon.

"Plain" vanadium steels are not greatly used.

**Vaucher's Alloy.**—An anti-friction white metal used for lining journals. Composition: tin, 18%; antimony, 2.5%; lead, 4.5%; zinc, 75%.

**Vein Tin.**—(See **Lode Tin.**)

**Vibrac.**—A nickel-chromium-molybdenum steel having a very high tensile strength.

**Victor Metal.**—A white metal of the imitation silver type. It has a very slightly yellowish cast. Composition: copper, 50%; nickel, 15%; zinc, 35%.

**Vienna Metallic Cement.**—This is an amalgam which is sometimes used as an imitation gold in cheap jewellery. Composition: copper, 86.4%; mercury, 13.6%.

**Virginia Silver.**—A nickel or German silver.

**Virgin Spelter.**—This denotes zinc which has been produced direct from its ore in one operation.

**Vital.**—An aluminium alloy of German origin. Composition: silicon, 0.6%; copper, 0.9%; zinc, 1.15%; manganese, 0.15%—remainder aluminium. Tensile strength, about 55,000 lb. per square inch.

Also trade name for a high carbon chromium, non-distorting tool steel.

(See **Hycc** and **Neor.**)

## VITALLIUM

**Vitallium.**—A cobalt-chromium molybdenum alloy also containing amounts of manganese and silicon. It was produced specially for the plates screws and small fittings used in the repair of broken bones.

The makers are the Austenal Laboratories, Inc., 34 West 33rd Street, New York.

**Vival.**—A French aluminium alloy. Composition: silicon, 0.5%; magnesium, 1%; manganese, 0.5%—remainder aluminium. Tensile strength, 53,000 lb. per square inch.

**Vivian's Copper Alloy.**—A nickel alloy of a whitish appearance. Composition: copper, 48.49%; nickel, 50.09%; iron, 0.82%; silicon, 0.3%.

**Vogel's Alloy.**—This is a file alloy. Composition: copper, 57 parts; tin, 28.5 parts; zinc, 78 parts; lead, 7 parts. Other similar alloys bearing the same name are known.

(See File Alloys.)

**Volatile Metals.**—All metals can be converted into vapour if they are heated to a sufficiently high temperature. A number of metals, however, are readily volatilised even by relatively moderate heat, such metals being known as the "volatile metals." They are: mercury, cadmium, sodium, potassium, arsenic and zinc. A number of the rarer metals are also fairly volatile.

**Volatility.**—The property of metals of being changed into vapour by heat. Most metals are volatile at high temperatures. Some metals, however, such as cadmium, mercury, zinc, sodium, bismuth, etc., are so volatile that they may readily be distilled.

Other metals, on the contrary, such as iron, platinum and tungsten, require the highest heat of the electric furnace to convert them into vapour.

## W

**Wad.**—A cobalt-containing mineral; a natural combination of cobalt and manganese oxides.

**Warne's Metal.**—An imitation silver. Composition: tin, 10%; bismuth, 7 parts; cobalt, 3 parts. It has a high melting-point and is fine-grained.

**Weisskupfer.**—German term. A nickel-silver. Literally, it means "white copper."

**Welding.**—The joining together by pressure of two pieces of metal which have previously been sufficiently softened for this purpose by the application of heat. The term usually denotes the joining of iron or steel in this manner.

Readily weldable metals are: iron, nickel, platinum, gold, silver, lead, tin.

## WOLFRAM

**Wessells Silver.**—An imitation silver alloy. Actually, it contains a small amount of silver. Composition varies, the following being the limiting amounts of the alloy's ingredients: copper, 51-65%; nickel, 19.32%; zinc, 12-17%; silver, 1.5-2%; iron, 0.5-1%.

**White Alloy.**—An imitation silver used in the jewellery trade. Composition: copper, 64.5%; tin, 32%; arsenic, 3.5%.

**White Arsenic.**—This is not metallic arsenic, but arsenic trioxide,  $As_2O_3$ . It is often known simply as "arsenic."

**White Brass.**—Generically, this name may be given to any alloy of copper and zinc containing less than about 40% of copper, since such alloys are pale in colour. It is, however, more frequently applied to alloys of copper, zinc and tin containing a minimum percentage of copper. Sometimes, indeed, the copper is entirely absent, and occasionally it is replaced by antimony.

**White Copper.**—A nickel or German silver.

**White Gold.**—There are many different types of white golds, some of them containing base metals. A high-class white gold is, however, a gold-palladium alloy containing 1 part of palladium to 6 parts of gold. This is silver-white in colour, hard, ductile and imperishable.

1 part palladium and 2 parts of gold form a greyish-white alloy.

**White Metal.**—A generic name given to all copper-zinc alloys containing more than 60% of zinc. Such alloys are silvery in colour. Strictly speaking, of course, they are brasses. There are many different varieties of white metal.

**White Pig Iron.**—(See **Pig Iron.**)

**White Tin.**—(See **Black Tin.**)

**Widia.**—Trade name for one of the brands of cemented carbides. It contains cobalt and tungsten.

(See **Tungsten Carbide** and **Cemented Carbides.**)

**Willemite.**—One of the oxide ores containing zinc. Chemical symbol,  $Zn_2SiO_4$ .

**Wilmil.**—An aluminium-silicon casting alloy similar to **Alpax** (which see).

**Wimet.**—Trade name for a series of cemented or sintered carbides. One of the cemented carbides containing cobalt and tungsten. English equivalent is **Widia**.

(See **Tungsten Carbides** and **Cemented Carbides.**)

**Wire Patenting.**—Method of heat-treating wires and rods to render them suitable for wire drawing. The steel is heated to allow the carbon to diffuse throughout the entire material, and then slowly cooled.

**Wolfram.**—Tungstate of iron and manganese, a source of tungsten. Wolframium.

## WOLFRAMITE

**Wolframite.**—One of the tungsten minerals. Chemical symbol,  $[(\text{FeMn})\text{WO}_4]$ ; wolframine.

**Wood's Metal.**—Perhaps the best known of the fusible metals. M.P.  $60.5^\circ\text{C}$ . Composition: bismuth, 4 parts; lead, 2 parts; tin, 1 part; cadmium, 1 part.

**Wood Tin.**—This is tinstone (tin ore), which shows concentric markings resembling a tree-trunk section.

**Wootz.**—A type of hard steel prepared by certain natives in India by a process similar to that of cementation. Malleable iron is put into a small crucible or pot together with about 10% of the leaves and stems of certain plants, the whole being then covered with green leaves and heated in a charcoal hearth until the mass of metal is completely molten.

**Wrought Iron.**—Produced by a process of burning out the various non-metallic impurities in pig or cast iron. Wrought iron softens at  $1000^\circ\text{C}$ . and melts completely at  $1550^\circ\text{C}$ . (cast or pig iron melts at  $1200^\circ\text{C}$ .). It is malleable and ductile and fibrous in structure, whilst pig or cast iron is brittle and crystalline in structure. Wrought iron can readily be rolled and also drawn into wire. Nowadays, much of its former uses have given place to steel, which is stronger.

**Wulfenite.**—A mineral containing molybdenum. Chemical symbol,  $\text{PbMoO}_4$ .

## Y

**Y Alloy.**—The first of the light aluminium alloys containing nickel. Developed during the last Great War by the National Physical Laboratory to meet the demand for a strong, light alloy for aero engine work.

Y alloy is a good all-round material. It may be had in both the cast and wrought forms. It is capable of considerable heat-treatment.

Typical composition: copper, 4%; nickel, 2%; magnesium, 1.5%; iron, 0.6%; silicon, 0.6%, the remainder being aluminium.

**Yellow Antimony.**—Also known as "alpha" antimony. This is prepared by oxidising antimony hydride gas at a low temperature. On exposure to light, it changes into "black" antimony.

**Yellow Arsenic.**—Also known as "alpha" arsenic. A variety of arsenic obtained by the rapid condensation of arsenic vapour. Sp. Grav. 3.7. It is devoid of metallic properties, but passes into the ordinary "grey" or "metallic" arsenic when exposed to light.

**Yellow Brass.**—“Best Yellow Brass” usually contains 70% copper, 30% zinc.

**Ytterbium.**—Metallic element. Chemical symbol, Yb; At. No. 70; At. Wt. 173·6.

A rare element discovered in 1907 by G. Urbain and named from its mineral source, the “yttria” earths found near Ytterby, a town in Sweden.

The element is sometimes named “Neo-Ytterbium” to distinguish it from an older “Ytterbium” which was found to consist of a mixture of two elements—Ytterbium and Lutecium.

Ytterbium metal is little known. It is greyish, like aluminium, and is only obtained with exceedingly great difficulty.

**Yttrium.**—Metallic element. Chemical symbol, Y; At. No. 39; At. Wt. 89; M.P. 1490° C.; Sp. Grav. 3·80.

First obtained by C. G. Mosander (1843) from the rare mineral earth *yttria* (named after the town of Ytterby, in Sweden, near which it was discovered).

Yttrium is a rare metal having a greyish cast and being similar to iron in appearance. Its light weight and high melting-point are noteworthy. The metal oxidises fairly rapidly in moist air.

## Z

**Zamak.**—(See *Mazak*.)

**Zeppelin Alloy.**—Analysis of the aluminium alloys derived from Zeppelins wrecked during the 1914–18 war gave the following average results: aluminium, 90·27%; zinc, 7·80%; iron, 0·45%; silicon, 0·37%; copper, 0·72%; tin, 0·11%; manganese, 0·27%. In some instances there were found traces of nickel.

**Zaratite.**—A basic carbonate of nickel.

**Zinc.**—Metallic element. Chemical symbol, Zn; At. No. 30; At. Wt. 65; M.P. 418·2° C.; B.P. 918° C.; Sp. Grav. 6·8 to 7·2; Sp. Ht. 0·0935; Coef. Exp. 0·00002976; Therm. Cond. (Silver = 100) 28·1; Elec. Cond. at 0° C. (Mercury = 1) 16·1.

Chief ores: Zinc Blende, ZnS; Calamine or Zinc Spar,  $ZnCO_3$ ; Red Zinc Ore, ZnO.

It is probable that zinc was known to the ancients. Basil Valentine (fifteenth century) first used the word “zinken” German *zink*—probably derived from *zinn*, tin) and Paracelsus, in the sixteenth century, first stated it to be a metal. In

## ZINC AMALGAM

comparatively recent times, pure zinc seems to have been first obtained by metallurgical processes about 1720.

Zinc is a bluish-white metal. It is brittle and, at a temperature of 300° C., can be powdered up in a mortar. Between 100° C. and 150° C. the metal becomes malleable, and can be rolled into sheet and drawn into wire. Good-quality zinc is capable of taking a high surface polish. In air, zinc slowly oxidises. When molten zinc solidifies it expands somewhat, thus giving perfectly sharp castings. Zinc is attacked by mineral acids, and when boiled with caustic soda or potash solution it dissolves.

Zinc forms a large number of alloys, the most important of which is brass. It is used enormously in the process of *galvanising* iron, which consists in coating iron with a film of zinc, the zinc preserving the iron from rusting and acting as a **Sacrificial Metal** (which see).

**Zinc Amalgam.**—Mercury and zinc form white, brittle alloys or amalgams, which tend to become pasty when the mercury is in excess. 1 part mercury, 8 parts zinc form a very brittle amalgam. Zinc rods used for Leclanché wet batteries are “amalgamated” merely by rubbing mercury over the zinc surface. In this instance, of course only a surface amalgam is formed on the zinc rod.

**Zinc Base Alloys.**—Alloys containing a large percentage of zinc are now chiefly used for die casting. (See **Mazak.**)

**Zincite.**—An oxide ore. Chemical symbol, Zno. 80·3% Zn.

**Zinc-Copper Couple.**—Name given to clean fragments of scrap zinc which have been immersed in a solution of copper sulphate and have thus been superficially copper-plated. They are used in synthetical chemistry as a reducing agent.

**Zinc Dust.**—(See **Zinc Fume.**)

**Zinc Fume.**—Also known as “zinc dust.” A greyish powder which collects in the pipes at the end of zinc furnace condensers. It consists mostly of zinc powder mixed with a little zinc oxide.

**Zinkalium.**—A zinc-copper-aluminium alloy. Composition: zinc, 12% ; copper, 3% ; aluminium, 85%. Is heat-treatable. Tensile strength, about 58,000 lb. per square inch. Brinell hardness, 100-120.

**Zircon.**—A mineral in which zirconium appears. Chemical symbol,  $(\text{ZrSiO}_4)$ .

**Zirconium.**—Metallic element. Chemical symbol, Zr ; At. No. 40 ; At. Wt. 90·5 ; M.P. 1700° C. ; Sp. Grav. 4·26 ; Sp. Ht. 0·066.

Occurs chiefly in the mineral Zirconite,  $\text{ZrSiO}_4$ , and in the various natural “zircons.”

First detected by M. H. Klaproth (1789) in zircon, and

named by him "zirconium." (The name "zircon" is derived from the Persian *zargun*, gold-coloured, in allusion to the hue of these semi-precious minerals.)

Zirconium, when fairly pure, is a lustrous, greyish, somewhat brittle metal, having a very high melting-point. It is very hard and will readily scratch glass. In its properties, it is closely related to titanium. Compounds of this metal are now being commercially produced in increasing amounts in America owing to the fairly recent discovery of large deposits of *zinconia*—zirconium oxide—in the mineral "baddeleyite."

Alloys of zirconium with iron and aluminium have been obtained and may be of commercial importance in the future, since zirconium is no longer a rare metal.

**Zirkonal.**—A German aluminium alloy. Composition: copper, 15% ; manganese, 8% ; silicon, 0.5% remainder aluminium. Brinell hardness from 170 to 190.

**Ziscon.**—A zinc-aluminium alloy made for instrument-work by Zeiss, of Jena. Has a specific gravity of 3.4 and a tensile strength of 10 tons per square inch.

**Zisium.**—A soft zinc-aluminium alloy made for instrument-work by Zeiss, of Jena. It also contains a little tin and copper. Sp. Grav. 2.95. Tensile strength, 5 tons per square inch.

### Chemical Symbols

Aluminium . . Al	Indium : . In	Ruthenium . Ru
Antimony . . Sb	Iridium . . Ir	Samarium . Sm
Arsenic . . As	Iron . . Fe	Scandium . Sc
Barium . . Ba	Lanthanum . La	Silver. . Ag
Beryllium . . Be	Lead . . Pb	Sodium . . Na
Bismuth . . Bi	Lithium . . Li	Strontium . Sr
Bromine . . Br	Magnesium . Mg	Tantalum . Ta
Cadmium . . Cd	Manganese . Mn	Tellurium . Te
Cæsium . . Cs	Mercury . . Hg	Terbium . . Tb
Calcium . . Ca	Molybdenum . Mo	Thallium. . Tl
Cerium . . Ce	Neodymium . Ne	Thorium . . Th
Chromium . . Cr	Nickel . . Ni	Thulium . . Tm
Cobalt . . Co	Niobium . . Nb	Tin . . Sn
Columbium . . Cb	Osmium . . Os	Titanium . . Ti
Copper . . Cu	Palladium . Pd	Tungsten . W
Erbium . . E	Platinum . Pt	Uranium . U
Gadolium . . Gd	Potassium . K	Vanadium . V
Gallium . . Ga	Praseodymium Pr	Ytterbium . Yb
Germanium . . Ge	Radium . . Ra	Yttrium . . Yt
Glucinium . . Gl	Rhodium . . Rh	Zinc . . Zn
Gold . . Au	Rubidium . Rb	Zirconium . Zr

## HEAT TREATMENT OF TOOL STEELS

**0.90% Carbon Steel.**—One of the most widely used—and abused—tool steels is the ordinary 0.90% carbon quality. The heat treatment of this steel should present very little difficulty. Care must be taken in heating to the quenching temperature (760° C.—780° C.) and that the attainment of temperature has not been too rapid, or that soaking at this temperature has not been maintained for too long or too short a time. Further, the actual quenching must not be “slipshod.”

With regard to the first difficulty. The tool must not be placed in a furnace which is already at the required temperature. This may sound obvious, but it is a process adopted nevertheless, with the result that the tools often crack owing to uneven expansion. This danger may be minimised by first warming the tool in front or on top of the furnace, and then placing it in the furnace, which should be at a temperature of about 500° C. The temperature should then be raised slowly, allowing at least as much time to attain quenching temperature as will be allowed at that temperature for soaking. Even longer may be required by very large masses. It is always desirable to follow manufacturer's recommendations if such are available when heat-treating specific alloys.

**Soaking.**—The second difficulty—soaking—is sometimes perplexing to the hardener, especially if the tool is of an intricate shape and has varying thicknesses of metal. In such cases, slow and uniform heating are essential to prevent warping and spalling of corners, etc. When the quenching temperature is reached, a good rule is to allow a half to three-quarters of an hour per 1 inch of thickness for soaking, taking into account the thickest parts.

**Quenching.**—Finally, there is the consideration of quenching. Most failures occur at this stage, but it is not always fair to blame the actual quenching. The difficulties dealt with above are perhaps the major causes, especially that of insufficient soaking, which, it will be readily appreciated, leaves the steel in a very unsatisfactory condition. The phenomenon of hardening is accompanied by a volume change (in the transformation of the austenite to hard martensite) and hence the seriousness of insufficient soaking will be seen, for not only will it result in “soft-spots,” but there will also be a tendency to cracking. Where possible in quenching, the thicker portions should be the first to enter the water, thus making the rate of cooling as uniform as possible. This precaution is necessary in order to reduce the

## HEAT TREATMENT OF TOOL STEELS

danger of cracking. With some tools it might be advisable to quench on a falling temperature, i.e. allowing the temperature of the surface of the tool to fall slightly, though still above the critical temperature before quenching. In this way the quenching speed of the whole of the tool is made more uniform. Quenching in this manner tends to eliminate the tempering effect which the hot interior has on the already cold and hard exterior, and consequently produces uniform hardness.

**Normalising Treatment.**—So much for the actual hardening of this steel. It might be advisable at this stage, however, to mention that successful hardening is greatly enhanced if, with all steels, a normalising treatment is given prior to hardening, in order to release machining stresses which are a frequent cause of distortion. Holes, such as bolt holes, should be plugged with clay, or asbestos wool, and if possible sharp angles should be avoided in the design. Intense stresses are set up at sharp corners, and these may be sufficient to crack the tool either in quenching or immediately after quenching. Stresses are unavoidable, and a wise plan is to remove the tool from the quenching medium when it is hand warm and temper at 100° C. for a short time to relieve these stresses. Dies and punches may not be required in the "glassy" hard condition, and so it will be necessary to increase the temperature or period of tempering. With this steel, however, it is rarely found necessary to exceed 250° C.

**Cold-Heading Die Steel.**—This steel, which is used quite extensively in cold-heading operations, differs very little from the one dealt with previously. It has a carbon content of 0.90-1.0% and a vanadium content of 0.20-30%. The effect of the vanadium is to give increased hardenability, grain refinement and resistance to shock. It also raises the hardening temperature to about 810° C. The same precautions as mentioned above in 0.90% carbon quality steels should be taken with this type.

**Oil-Hardening Die Steels.**—The chances of breaking of tools are considerably lessened when oil-hardening steels are used, since the quench is not so drastic. For a typical example an oil-hardening non-shrinking die steel will be taken. It has an analysis as follows :-

Carbon . . . . .	0.90-1.10%
Chromium . . . . .	0.50-0.60%
Vanadium . . . . .	0.25%
Manganese . . . . .	1.2-1.5%

The dimensional changes in hardening are very small, hence the property of non-shrinking or non-distortion. The hardening temperature generally adopted is 760° C.-780° C. although the steel may be hardened from 800° C. without any grave conse-

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quences. This may lead to a slight coarsening of the grain, however, which should be avoided wherever possible. The "golden rule" is, therefore, "use the lowest permissible temperature in all heat treatment." The same procedure and precautions in heating and method of quenching as with the 0.90% carbon steel are advisable, although the allowance of a little longer time for soaking may be beneficial. Water quenching must never be adopted. With regard to the tempering, this is, of course, decided by the purpose for which the tool is to be used, but it is carried out in much the same way as with a carbon steel.

**High Carbon-Chromium Die Steels.**—Whilst on the subject of steels, which are essentially die steels, it would be most opportune to discuss a highly alloyed quality. A very popular steel is the high carbon-high chromium type, containing 2.0-2.25% carbon and 12-14% chromium. Given proper attention during heat treatment, this steel does not show any appreciable movement or distortion, but rapid heating and undersoaking result in very serious distortion. Because of the high proportion of chromium carbide in the steel, the soaking times must be carefully controlled as the solution of this constituent is rather sluggish. It has been found that at least 1 hour per inch of thickness is necessary, but excessive soaking results in alarming grain growth. The temperature range (950° C.-980° C.) should be strictly adhered to and must not exceed the upper limit, otherwise the grain size will be seriously affected. The steel is generally quenched in oil, taking all the usual precautions to prevent distortion. However, in certain cases where design or size makes quenching inconvenient, or difficult, and where intense hardness is not required, cooling in a strong air blast is sufficient to give a Rockwell hardness of 55-58 "C" Scale, as against 66 "C" Scale with oil quenching. Care must be taken in cooling with air blast that the rate of cooling is the same in all parts of the tool. Tempering again depends on the ultimate purpose of the tool. Temperatures of 150° C.-200° C. will be found to be sufficient to relieve stresses without reducing the hardness, but where the hardness must be reduced, tempering can be carried out at temperatures up to 550° C., depending upon the hardness required. Whilst this steel has not at any time a high toughness value as interpreted by Izod figures, it will be found that tempering for short periods at the higher temperatures will give better results in this direction than long periods at very low temperatures.

Since this steel is very susceptible to grinding cracks when in the hardened and tempered condition, some die manufacturers finish their products with a mirror-like polished surface, and as any hardener who has been faced with such dies knows, these

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jobs are veritable nightmares, since the manufacturer expects the tools back just as he sent them. One satisfactory method is to pack the articles in a small carburising box or welded box of heat-resisting material, using spent charcoal as the packing medium. The soaking period is then greatly increased, and as the sizes of boxes and tools vary, there can be no hard-and-fast rules, but experienced hardeners will soon become familiar with the method. When the boxes are brought from the furnace they are opened, and the articles gripped with suitable tongs and quickly quenched. Thus they are exposed to the air for a minimum amount of time. When there are a number of articles in the same box, it is advisable to have the help of assistants. This method will be found to give astonishing results, and all that will be necessary, after suitable tempering with similar precautions, will be a light polish of the tool faces.

**Finishing Steels.**—The next steel to be discussed is a "finishing steel," so called because of its use in trimming tools, to impart a "high finish" to the product. The carbon content is about 1.5%, tungsten about 4%, and chromium about 5%. This steel is a water-hardening quality, requiring a hardening temperature of 830° C.-850° C. For good results, it is absolutely essential with this steel that heating, soaking, and quenching be carried out with extreme care, otherwise broken tools will easily outnumber the good ones. Drawing dies, etc., which have holes through them, must be treated with special precaution. This steel hardens intensely (67 "C" Rockwell), but it does not always harden throughout. This depends, of course, on the section. In other words, there is developed, after heat treatment, a hardened case with a soft, tough centre. The depth and uniformity of the case depend entirely upon the observance of the above points. A light tempering at 200° C. is essential immediately after, or just before, the tool reaches room temperature, in order to relieve the stresses.

An extremely useful property of this alloy is its expansion hardening. This is particularly useful with drawing dies. When a die has worn to its limits, it can be normalised and rehardened. It will then be found that the hole has shrunk, so that it can be polished to size, or some required size again. This process may, with care in heat treatment and judicious use of the die, be repeated as many as six times before the die finally breaks or before the bore becomes too large. When carrying out this process, attention should be paid to normalising. It must be remembered that this steel hardens intensely and not throughout, and consequently is very highly stressed. Sudden changes in temperature, and resulting expansion, are liable to cause bursting. Hence the heating for normalising, which is, of course, to remove the stresses, should begin at a fairly low heat.

**Hot-Forging Die Steels.**—There are quite a number of members in this class, but the heat treatment is essentially the same for all, there being only a slight variation in the hardening temperatures. The difference in analysis are not great, but they do impart certain special features which in turn depend upon the heat treatment for good results.

The carbon content is about 0.30%, tungsten 8-9%, although some of the steels have a much lower tungsten content, and chromium varies between 2% and 4%. Some of these alloys have small additions of vanadium and molybdenum and about 4% of nickel. These latter elements are present either singly or in various combinations depending upon the ultimate purpose of the steel.

Preheating at 800° C. is advisable since the hardening range is 1,100° C.-1,200° C. The steel is usually oil quenched, although air-hardening gives a very satisfactory hardness. The hardness after quenching should be about 470-500 Brinell. Tempering is necessary to reduce stresses, but where the hardness has to be lowered, it will be found that no appreciable change is effected until a temperature of 650° C. is reached. It has been noted that in the majority of cases a Brinell hardness of about 350 gives very satisfactory results, but the user of the steel would be well advised to consult the manufacturer when in doubt.

A reasonable tolerance for finishing should be left on the dies and punches, etc., since this steel is somewhat prone to scaling. A useful method of minimising this trouble is to "paint" the article with a paste (made with water) of china clay and powdered charcoal in equal parts. The hardness is not affected by the paint and should it adhere it can be easily removed by a strong wire brush. Provided the steel is tempered back to a suitable hardness, it is one of the most trouble-free.

**High-Speed Steels.**—Finally, we must deal with high-speed steels, and although the treatment may seem straightforward, the number of questions that might be raised are far too many to consider here. There are several types of high-speed steel, but the precautions to be taken are essentially the same and are necessary to each quality. The consideration of temperatures is fairly simple. Preheating for all the steels should not be excessive either in time or temperature. Steels containing 14% tungsten should be transferred then to a furnace at 1200° C.-1250° C., and after soaking carefully and thoroughly, the time depending upon the size of the tools, they should be withdrawn and cooled in an air blast. Oil quenching of this particular alloy often results in the tool splitting. The 18% tungsten highspeed steels are oil-quenched from 1250° C. to 1300° C., although in certain cases air blast may be an advantage, especially where intricate designs are involved. The super high-speed steels containing

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5% or 10% cobalt have gained much favour recently because of their extremely good performances at high speeds. They require a little higher temperature to obtain the best results, viz., 1300° C.-1350° C. Correct soaking at super-heat ensuring a complete solution of the carbides is the key to good results. Should the tool be insufficiently preheated, it will be found that the prolonged soaking of the tool, in order that it may obtain correct quenching temperature, will result in rapid growth in the thinner portions, and in all probability "burning" will take place, which will ruin the tool, or at the very least, lower its efficiency and life. Excess gas should be used in the furnace, unless a modern controlled-atmosphere furnace is available. The use of excess gas will tend to reduce scaling and decarburisation.

**Secondary Treatment.**—So much for the first part of the treatment, but as most users know, a secondary treatment is necessary. The temperature range employed for this purpose is 560° C.-580° C. The time, however, varies with the size of the tools, but in general three quarters of an hour suffices. Cobalt high-speed steel require another treatment at this temperature, preferably after an interval of about twenty-four hours, in order that the secondary hardness property may be fully developed.

High-speed steels are usually required to conform to certain hardness specifications. If these figures are not obtained, on no account must the tool or tools be re-treated without an intermediate annealing or normalising. Should this precaution be omitted, the steel will tend to be brittle. An almost infallible indication of this treatment is the "fish-scale" looking fracture which is obtained when the tool breaks, and if this were subjected to preparation and examination under the microscope, an enormous grain size would be revealed.

**Butt-welded Tools.**—Butt-welded tools are given essentially the same treatment as ordinary tools, but cooling in an air blast should be used to avoid cracking at or near the weld. Another branch in high-speed tools is that of carbon steel shanks tipped with a small piece of high-speed steel. The preparation of the shank and tips is, of course, the work of the toolroom, but the tipping and heat treatment falls to the heat-treatment department. The prepared tip bed in the shank should be covered with a layer of some well-known brand of welding compound, such as tip-weld, and the tip then placed on top in its correct position. A little more compound should be placed at the vertical junctions. The shank and tip are then preheated as usual in high-speed steel hardening, and then transferred to the high-temperature muffle (keeping an excess of gas to minimise oxidation). When the tip and end of shank have attained the correct hardening temperature, and after proper soaking, the tool should

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be removed and a firm steady pressure applied to the tip. The tool should then be cooled in an air blast until it reaches black heat, at which temperature it must be transferred to the tempering furnace (at 560° C.-580° C.) for the secondary treatment.

Some of the aluminium alloys are improved by correct heat treatment. In the course of time an increase of hardness can occur in an alloy where some constituent is more soluble at a high temperature than at a lower temperature, and where rapid cooling fixes this constituent in supersaturated solid solution. Being supersaturated and metastable at lower temperatures, there is a natural tendency, slightly at ordinary temperatures and more rapidly if the temperature is slightly raised, to precipitate out of solid solution some of the dissolved constituent. Precipitation of the excess constituent occurs in the form of submicroscopic particles distributed throughout the mass of the solid solution, and this causes hardening. The solution treatment of such alloys is usually applied, and temperature depends on the composition of the alloys. The duration of heating depends upon the mass of the article. The soluble constituent of the alloy must go into solid solution before quenching and exact temperature control is essential. For solution treatment rapid heating is necessary, but it should be remembered that these alloys are soft during this operation, and especial care is necessary to prevent the decomposition of the solid solution.

## PRACTICAL HINTS ON HARDENING AND TEMPERING

THE higher carbon content present the lower is the hardening temperature ; thus a cast tool steel containing 1.4% carbon will harden at a lower temperature than one having 0.5%. Incidentally, both steels are used for different classes of work, and whilst the former will produce the glass hardness requisite for machine cutting tools, the lower grade is intended for such services as providing a comparatively thick, hard surface on a low-carbon steel when the two are welded together and subsequently hardened.

The means used to bring the material to the desired temperature before quenching may consist of an open fire, torch, muffle furnace, or other device specially constructed for the work. While an open fire may be suitable for hardening such articles as cold chisels, good results are not likely to follow from a general adoption of this practice.

The first essential of good hardening practice is to secure uniformity of temperature, and where a flame is impinging directly on to the work the attainment of such a condition is impossible. This is particularly so where the mass of steel being hardened is unevenly distributed, as, for instance, in a screwing tap. Such a part is bound to receive most heat at the thinnest points, namely, the threads, when the resultant hardening would be unsatisfactory. Another important point is the prevention of scale formation on the work during heating. This is almost impossible where the work is open to the atmosphere during the process. Further to this, some means of temperature control is necessary, meaning that some form of chamber is required in which the heating of the part can be carried out to ensure that uniformity of hardening may be repeatedly attained with assurance.

**Muffle Furnaces.**—Suitable furnaces may be heated by gas, oil, or electricity. Briefly, they consist of a firebrick-lined chamber fitted with a door to permit the entry and removal of work, the interior of which is capable, by regulation of the heating medium, of being maintained at the desired temperature for the requisite period.

Certain forms of this class of furnace for the hardening of large quantities of small articles are arranged for continuous operation, the parts being fed on to a moving chain grating travelling at such a speed through the heated chamber that they are ready for quenching when they have passed through. On

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emerging from the furnace the parts fall off the end of the grating directly into the cooling bath.

**Hardening Baths.**—Another method is to immerse the parts to be hardened in a bath of molten lead or metallic salts which is maintained at the desired hardening temperature. This method is particularly suited for the hardening of slender or intricate parts in the nature of taps, dies, and light parts. The advantage of this method is that no portion of the work can reach a temperature other than that of the bath, and, therefore, absolute uniformity of heating results.

**Indication of Temperature.** The use of a pyrometer is a necessity where hardening is an operation that is regularly carried out. Most common of these is the thermo-electric type, in which the action of the heat on the thermo-couple, housed in a tube inside the muffle or in the bath, creates a current which is registered on a meter calibrated in degrees Fahrenheit or Centigrade. Other forms are the resistance and optical-type pyrometers.

Another method that can be employed where the amount of hardening does not warrant the adoption of more expensive but nevertheless reliable apparatus is the Sentinel cone. These cones are composed of mineral salts or substances which are placed in the hardening chamber. The cones are graded by means of numbers, indicating the temperature at which they melt. Thus a cone is selected which will melt when the interior of the furnace reaches the desired temperature. When such are employed the directions for use should be carefully studied.

**Judging Temperatures by Colour.**—The judgment of high temperatures by colour can be, by skilled persons, estimated with fairly close approximation. However, the conditions of lighting under which the viewing takes place cannot be constant, and therefore may be considered unreliable, depending as it does so much upon the skill of the operator. As an aid to such judgment a colour chart ranging from dull red ( $515^{\circ}$  C.) to white ( $1,320^{\circ}$  C.) is sometimes included in a steel manufacturer's list. A chart of this description is certainly handy, and it is intended to be used in daylight, but it naturally follows that on a dull day the colour of the heated metal may appear brighter than is really the case for purposes of comparison.

Lower temperatures are more easily judged where the steel is polished by the colour of the oxide film which appears on the heated surface. The colour ranges from pale straw ( $220^{\circ}$  C.) to dark blue ( $316^{\circ}$  C.). Here again temperature charts are available for comparison. In both cases, however, the colours are dependent on the colour-printing, and should be taken as a guide only, experience being gained in the light of the results obtained.

Having heated the steel to the correct hardening temperature, or slightly in excess to allow for temperature drop during transfer

## PRACTICAL HINTS ON HARDENING AND TEMPERING

to the bath, the part being dealt with is immersed in the cooling medium. The object should be in the majority of cases to secure cooling at an even rate and as rapidly as possible. The nature of the coolant is dictated by the class of steel used and may consist of water, water and oil, brine, oil, or air.

High-carbon steel hardens in water, and if the formation of the part made from this material is such as is likely to induce the formation of hardening cracks, a layer of oil is sometimes used on the surface of the water. Most of the tool steels now in use fulfil the same purpose, but are oil-hardening, in which the risk of deformation and cracking is greatly minimised if not entirely eliminated.

Where the bath is being frequently used or the mass to be hardened is sufficient to cause an appreciable rise in the temperature of the coolant, some means of dissipating the heat generated is introduced. The means used generally consists of water-cooling, either by circulating the coolant through pipes surrounded by water or circulating water through pipes situated in the cooling-tank.

**Case-Hardening.**—For water-hardening, clean water should be used at a temperature not lower than 60° F. Soft water is preferable to hard, and it is often beneficial to introduce a proportion of washing-soda to the water to create this effect. Hardening oil should have a high flash-point, be comparatively thin, and not readily become gummy. Special oils are made for this purpose.

Carbon steels having a low carbon content and which do not respond to direct heating and quenching may be surface hardened after treatment to introduce additional carbon. This process is known as case-hardening. The hard case so obtained is in the form of a skin, the depth of the case depending upon the duration of the process employed.

In thickness the case may vary according to circumstances from a mere skin of a few thousandths of an inch to anything up to  $\frac{1}{8}$  inch. This is entirely dependent on the service for which the part is required, and also if a proportion of the hard surface needs to be subsequently removed by grinding. For ordinary commercial purposes the depth of the case ranges from  $\frac{1}{32}$  in. to  $\frac{1}{16}$  in.

**A Simple Method.**—The simplest method of case-hardening is to heat the steel to a bright red and either apply "rapid" case-hardening compound by dusting on to the heated surface or rolling the part in the powder. After allowing sufficient time for the compound to melt on the surface of the work, it is reheated and the process repeated two or three times, finally heating and quenching in water. This has the effect of producing a thin-glass-hard skin and is suitable for many purposes, the main

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advantage lying in the fact that the operation is a quick one. If a deeper case is required the work is packed in steel or iron boxes surrounded by a carbonaceous material, such as charcoal, specially prepared for carburising steel, the lid of the box being sealed with fireclay to exclude the entry of air. The box is then maintained in the muffle at a temperature of 900° C. for a period of from four to ten hours, according to the depth of penetration required. If the work is then removed in the heated condition and quenched the parts are surface hardened. If a specimen so treated is broken, the depth of penetration of the case shows in the form of a fine-grained ring of metal surrounding a more or less coarse-grained core. A refinement which normalises the core consists of allowing the box to cool down, without unpacking, and reheating to 800° C. and quenching the parts and reheating to 750° C. and quenching again. The treatment recommended by the makers of the steel used should be followed to secure the best results. Another method similar to the foregoing has gained prominence in recent years, the difference in the process is that gas is passed through the boxes for the same purposes that the solid material is used.

**Cyanide Hardening.**—Small objects are to a great extent treated in a cyanide furnace. Here molten potassium or sodium cyanide is maintained at a certain temperature in a steel pot and the work soaked in it for the requisite period to give the desired depth of case, after which the parts are removed and quenched.

**Tempering.**—Tempering is carried out where necessary in a bath of oil at the required temperature. Smaller parts which may need to be tempered by visual means are polished and reheated on a hotplate or in a bath of hot silver sand. Where sand is employed, the temperature of the work may be more easily controlled and the tempering localised more readily than with a hotplate.

## THE SPRAY METHOD OF COATING SURFACES WITH METAL

THE spraying of metals or other surfaces with metal is a skilled operation. Aluminium, gold, lead, nickel, silver, tin, and zinc have been successfully sprayed on to surfaces, while, on account of the rapidity of the process, there is hardly any oxidisation. It is probable that electro-plating on iron, of brass, bronze, copper, silver, and gold, will hold the field for some years to come. For these metals, when sprayed, do not seem to produce a sufficiently homogeneous coating to prevent the iron or steel corroding and rusting when brought into an acid atmosphere, or in contact with electrolytes.

**Preparation of the Surface.**—Prior to metal-spraying it is necessary to roughen all surfaces; this is done either by sand-blasting or by blasting with steel grit so that a rough mesh-like effect is produced on the metal. Such a fine structure in a way matches the size of the particles of the finely divided metal in the molten spray.

Cleanliness is essential, of course; metals in the finest state of division simply will *not* adhere to any surface unless it is absolutely free from dirt, and the same precautions which have to be taken in electro-plating are likewise important in hot-metal spraying. A deposit appears to be made up of countless granulations formed as each particle rapidly cools. These particles before solidifying become coated with a minute film of oxide, but this does not prevent the entire deposit from holding firmly together by the partial fusion of each semi-fluid particle, the whole coating adhering to the actual metal surface through the minute net-like surface effect of sand-blasting.

The metal in its transit from the blowpipe feed consists of many millions of isolated globules of molten metal, which partially flatten themselves against the surface to be coated as the result of an intense collision or, if we like, through a heavy bombardment somewhere in the neighbourhood of a speed of 12 miles per minute. Each particle has a diameter approximating a hundredth of a millimetre.

**Method of Melting.**—The fact that a fine wire when placed in the hottest zone of a blowpipe flame becomes white-hot and then molten—forming globules—is the basis of the metal-spray process. If the globules of fluid metal fall into the path of a high-velocity current of gas, they are immediately broken up into a continuous stream or spray of molten metal. A blowpipe, incorporating a suitable high-pressure gas supply nozzle, forms the spray-metal tool.

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According to the metal used for spraying so is the structure of the surface produced. The essential difference between the structure of a casting lies in the fact that in the latter there is an almost continuous layer (upon layer) of fine metal particles separated by the inclusion of imprisoned gases. Whereas, in a sprayed-metal surface, instead of such gas spaces there are minute films of oxide separating each particle. A considerable difference attaches to the close structure produced by the metals of lower melting-point. In this case, the particles are much smaller and form far finer spray than metals like nickel, gold, etc. This fact renders it necessary to give a thicker coating of the higher melting-point metals.

It was previously mentioned that there was a slight oxidation of the molten particles themselves on reaching the metal surface, but this does not apply to the metal wire itself in its passage from the blow-pipe flame to the surface. Proof of this is witnessed in the complete freedom from burning of magnesium, of all metals. As in the case of metal-hardening by rapidly bombarding it with blows (or the impingement of steel balls as in the later methods) so in metal-spraying, the film of deposited metal is slightly harder than the same metal when cast while its density is a little less.

These slight variations make for certain alterations in the working of sprayed-metal articles, such as higher speed and lighter cut when machining, chiefly perhaps to prevent peeling of the particles by cutting it directly through them, instead of "cut-shearing" them. Polishing offers no difficulty whatever, the usual methods being used.

**Aluminium Spraying.**—Of all metals, aluminium probably offers greatest scope in industry, both on account of its durability on exposure and fairly good conductivity. It is notoriously difficult to electro-deposit aluminium—results are so uncertain. Aluminium, as far as its electro-deposition is concerned, is a most evasive sort of metal; far and away better results apparently have been obtained by the spraying method.

The aluminium film or oxide is remarkably strong and the metal adapts itself admirably for spraying even for large areas and bulky structures. Temperature of working is rather critical; above a certain limit rapid absorption takes place, and as a protective coat the deposit becomes useless. This temperature limit is 970° C.—this being about 310° C. above the melting-point of aluminium. Iron articles which are spray-treated with aluminium form an exceedingly hard alloy with the latter, which then oxidises to form a scale-free coating. Alternate spraying of aluminium and zinc is most advantageous in many instances successive layers of the two metals producing a most adherent protection.

## THE SPRAY METHOD OF COATING SURFACES WITH METAL

**Tin and Lead Spraying.**—The two metals tin and lead adapt themselves to the spraying process, for the former, on account of its feeble reactivity, is ideally suited to the preservation of foodstuffs and is one of the most useful of the common metals. Unfortunately, it seems that sprayed tin requires to be of fairly good thickness, considering the rather porous nature of the metal. Most pots, pans, and other culinary utensils need only a light deposit of tin, which is ordinarily too porous, so to overcome this the film is coated with a layer of varnish. The general thickness of tin deposits is about  $\frac{1}{4}$  of an inch, which is quite considerable and just shows what may be achieved with the metal spray. Deposits of  $\frac{1}{100}$  of an inch of the tin coating are also usual and are very protective. It should be remembered that tin is a really beautiful metal and it is almost remarkable that more use is not made of it for ornamental purposes and motor-car fittings, etc. Its price is fairly high, of course; about £230 per ton as compared with copper at £44 per ton.

Lead, principally associated with the definite protection of metals against acid fumes owing to its great acid resistance, requires a limit of deposit thickness for the latter purpose of  $\frac{1}{16}$  of an inch.

**Nickel and Silver Spraying.**—The chief advantage in the spraying of nickel lies in the fact that great areas may be covered; such would be impossible in the electro-plating of the metal. In this manner huge rolls of sheet iron are easily treated, the size of which would absolutely preclude them for entering the largest plating-vat made. The use of the nickel spray, however, is decidedly limited, far better results being obtained by the electric method on account of the brilliance of the latter deposit. Thus far, therefore, such spraying appeals only to the commercial and bulk handling of large and unwieldy articles and machinery.

In the case of silver, no particular advantage can be claimed over the electro-deposition method, since any thickness may be obtained by the latter process coupled with many pleasing variations from a matt to a bright finish. Some intricate filigree work may, perhaps, be more effectively treated with the molten-spray method than by electro-depositing, but it is doubtful. Generally speaking, the size and nature of articles for silvering adapt them to the plating-vat rather than the spray. One advantage perhaps of the latter might be in the direct application of silver to iron and steel, which do not require to be coppered beforehand as in the case of electro-silvering.

**Copper, Brass, and Zinc Spraying.**—The remarks which apply to copper also do to brass and bronze, etc. As a protective coat, brass is often applied to iron, as it also is for ornamental purposes, but a certain thickness is essential. Since steel and iron are by far the commonest bases to which copper and brass

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are applied, the porosity of the latter metals is important to consider ; this is partly due to the largeness of the particles of molten metal—repeated layers of brass and copper are needed to give a perfectly homogenous and close skin. What happens if this is not provided is this : When brought into an acid atmosphere, or alkaline for that matter, and even damp, the under-surface of steel or iron becomes corroded and gradually oxidised, so that the otherwise protective coating of copper or brass peels off. Thickness of deposit alone is not all that must be considered, for the same peeling effect is liable to occur if the article is damaged in any way so that the coat is scratched. Indeed, this is the most important thing to guard against in all coated metals.

Zinc is chiefly used as a coating to iron, and the incorrectly so-termed "galvanising" usually consists in dipping the iron articles in molten zinc. Electro-galvanising is done as well, of course, but on a large scale dipping is the general rule. As a protection, zinc must be pure, and this purity is ensured by using the spray method of application. It particularly commends itself to the treatment of small articles and is an extremely economical process, since the thickness of zinc sufficient to prevent rusting and corrosion need not exceed  $\frac{1}{60}$  of an inch. The thickness of deposit naturally depends upon the use to which the articles are to be put, for most purposes twice the above thickness being usual for the prevention of atmospheric corrosion. Zinc, it has already been mentioned, is often sprayed in conjunction with aluminium, the effect being an ideal, tenacious deposit.

**Gold Spraying.**—Porosity, again, is the chief deterrent in the spraying of gold and, since additional thickness would be prohibitive in most cases, the porous nature can only be checked by using suitable varnishes. However, the same remarks here apply as to silver, for both metals are what may be termed "luxury metals," principally being used for ornamental and artistic effect. Sometimes it is necessary to have appliances covered with gold—as in some laboratory apparatus. On steel, the metals, gold, silver, copper, and brass appear to be best deposited electrolytically, very little dissatisfaction arising therefrom.

The factor to be taken into consideration in the spraying of metals is the convenience and facility of adhering to the ground-surface. As has been indicated, this is of decided advantage in the case of metals like aluminium, the electro-deposition of which is a difficult process—such a difficulty being removed by spraying. We have chiefly dealt with the spraying of metal upon metal, but it is equally important to understand that certain bodies—wood, plaster, unglazed porcelain, etc., are quite easily treated by spraying. In their case the process seems to be far

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more convenient than the usually messy pre-electrolytic preparation—treating carbon-disulphide and phosphorus or brushing with graphite—to obtain a good conducting surface. Certainly, metal-spraying holds out great possibilities and is an attractive and fascinating subject.

**Repairing Worn Parts.**—The spray method of coating metal surfaces can be employed to repair worn and broken metal parts. Such parts can be built up to their original size, either by the electro-chemical deposition of metal, or by the metal spraying process. The usual method is to deposit, by means of one of these two processes, sufficient metal on the surface to be repaired, to make it oversize. It is then machined, filed or ground to correct size. The advantage of this process is that it is cheaper than the cost of replacement and it is quicker. It is not applicable in all cases, but where it can be adopted it is cheaper than welding or brazing, and it avoids the possibility of the distortion of the metal due to the heat effects of other processes. The metals commonly used for spraying are stainless steel, high carbon steel, iron, nickel, monometal, copper, brass, aluminium, cadmium, tin, and lead. It is possible to apply heat treatment to deposited carbon steels. Metal surfaces to receive treatment by metal spraying are usually prepared by sand blasting to give a clean surface, where the metal to be sprayed is only intended as a protective coat. Where it is intended that the sprayed metal should build up a worn part, it is desirable to machine the part and to leave the surface resembling a coarsely-cut screw thread.

## RUSTPROOFING IRON AND STEEL

THE commonest method of preserving ironwork from rusting is, of course, to paint or enamel it or to brush over it some coating of varnish which will serve to keep the air out of contact with it. Such methods have their advantages, but they cannot be applied in every instance. One of the drawbacks of varnishing or painting a metal surface, for instance, is that the appearance of the surface is changed, minute markings on the metal surface which it may be desirable to preserve are filled up, and a film or skin of foreign matter is laid on the surface of the metal. Paints, varnishes, and enamels all tend to crack away from the metal surface in time, and thus to expose the bare metal underneath to rusting influence.

**Altering Nature of Steel.** Steel may, of course, be rust-proofed by altering its composition. By incorporating, for example, certain proportions of nickel and chromium with ordinary steel, we obtain the well-known "stainless steel" which is in a high degree not only rustless, but also untarnishable. Such procedures, naturally, do not come strictly within the category of rustproofing methods for iron and steel, and they are merely referred to by way of incidental interest.

The best way of rustproofing iron or steel is to rust it! The statement may appear to be paradoxical at first, but nevertheless it is a perfectly correct one. Iron (and steel, also, for it is merely a special form of iron containing carbon and traces of other elements), when it is exposed to moist air containing traces of carbonic acid (carbon dioxide), forms on its surface the well-known and characteristic "rust," which consists mainly of iron oxide mixed with iron carbonate. There are, however, more iron oxides than one. There is, for instance, a black iron oxide containing a minimum proportion of oxygen. If, by chemical means, the surface of the iron and steel is oxidised to this black oxide, an exceedingly fine and hard coating of the oxide is formed which resists all further oxidation. Hence iron in this chemically oxidised condition becomes highly rustproof, and changes very little in appearance.

**Oxidising Iron Articles.**—We may oxidise iron articles by heating them to redness and then holding them in a jet of steam escaping from a kettle of boiling water. This process is, indeed, the basis of the Bower-Barff process of rustproofing iron and steel articles. By means of it, the iron becomes coated with an extremely fine layer of black iron oxide which resists all further oxidation. On a small scale, this method of rustproofing is only suitable for treating nails, screws, and other small articles which

## RUSTPROOFING IRON AND STEEL

can be conveniently held in a small steam jet after being heated to redness.

Another method of rustproofing steel or iron articles consists in immersing them for a few minutes in a bath of molten saltpetre. Here again, however, the method is only applicable on a small scale to diminutive articles. It has been employed frequently for the bluing of clock hands, a quick dip of the articles into the molten saltpetre being sufficient to obtain a blue-black colouration on their surfaces. A very serviceable oxide coating on iron and steel articles may be obtained by rubbing the articles over with a paste made of thick oil and fine sawdust, and in heating them on a shovel or an iron tray over a slow fire until the oil paste burns completely away. The articles are then scrubbed under hot water and dried quickly. A dull, greyish black finish—the characteristic "burnt-oil finish"—is thus obtained. It is suitable for all indoor metalwork, but it is doubtful whether iron and steel articles so treated would stand up to rusting influences in permanently exposed situations.

**The Use of Oil.**—All the above "oxide coatings" on iron and steel are much improved in rust-resisting efficiency as well as in appearance by having oil rubbed over them. The oil is absorbed and tenaciously retained by the extremely fine particles of black oxide formed on the iron or steel objects, much in the same way as dye is absorbed and retained by cloth. This extremely fine oil film, together with the fine particles of black oxide present upon the metal surface, confer very high rust-resisting properties to the latter.

By far the most popular rustproofing method for iron and steel articles is the coslettising process, a method which was originally devised in 1907 by Thomas Watts Coslett, an English chemist, but developed in America. Coslettising is very simple to carry out. The iron or steel articles to be treated should be well cleaned, preferably by having been previously immersed in a bath of weak sulphuric or hydrochloric acid for a few minutes to dissolve away their surface impurities. After a brief rinse in clean water, the cleaned articles are immersed in the hot coslettising bath, which consists of a moderately dilute solution of phosphate of iron (ferric phosphate), containing a small amount of phosphoric acid.

To prepare this solution we may add about a dessertspoonful of phosphate of iron to every quart of water used. The phosphate of iron will not dissolve in the water alone, but on adding a few drops of phosphoric acid to the water it will dissolve readily.

**Coslettising.**—The method of coslettising is carried out in the following manner. The coslettising bath is heated by being rested over a saucepan containing boiling water. The articles to be coslettised should be immersed in the bath for about half

an hour, being frequently turned over in order to ensure that the chemical action takes place equally all over their surfaces. The steel and iron articles turn grey almost immediately after they have been immersed in the bath. Bubbles of hydrogen gas are evolved from their surfaces, but the metalwork is not dissolved away.

After half an hour's immersion in the hot (nearly boiling) coslettising bath, the articles should be withdrawn, well washed in water, and dried. At this stage they will have a grey colour, but on being rubbed over with oil they will acquire a soft dull-black finish and will be absolutely rustproof. The fine "film" formed on the metal surface is composed of a mixture of iron phosphate and iron oxide. This protecting "skin" is so exceedingly thin that it follows the contours of every microscopic irregularity on the metal surface. Yet it is hard, tough, and extremely wear-resistant.

Coslettised iron and steel may, of course, be painted, varnished, or enamelled, such surface films adhering extremely well to the treated metal surface.

The commercial rustproofing process known as "Parkerising" is merely another form of coslettising, and was originally developed in America by the Parker Company of Detroit. It consists essentially in the employment of a patented mixture of iron and manganese phosphates in the rustproofing solution. Another similar modification is the process known as "Bonderising," which is commercially employed to form a base-coating on iron and steel for finishing with paints and lacquers.

**"Granodising" Process.**—By immersing iron and steel in a hot solution of zinc phosphate acidified with phosphoric acid, rust-proof coatings may be formed. This particular bath lends itself to electrolytical employments, the "granodising" process of rust-proofing consisting simply in making the iron or steel article under treatment the cathode or negative electrode of the bath, the positive electrode of the bath being a plate or rod of carbon. Iron and steel articles which have been "granodised" in this manner acquire a dense black coating which is highly resistant to all atmospheric influences. An advantage of the granodising process is that it can be applied to articles of zinc, cadmium, and other metals, in addition to those of iron and steel. The granodising electrolytical process can be operated on a small scale by means of a 6-volt accumulator, the distance between the negative and positive electrodes in the bath being kept as small as possible. Granodising gives a thicker coating to the metal surface than coslettising, and the thickness of the rust-resisting film formed on the metal may to a large extent be governed by the current strength of the bath and the duration of the treatment.

## ELECTRO-PLATING

IN electro-plating a solution of some salt of the metal which it is desired to deposit is placed in a suitably shaped container, across the top of which is placed a pair of (sometimes three) metal rods. From one of these rods the article to be plated is suspended by means of a piece of wire, while a plate of the same metal as that in the solution is suspended from the other. If an electric supply is then connected to the two rods, so that the positive terminal (anode) is connected to the plate and the negative (cathode) to the article to be plated, then the chemical action caused by the passage of the current through the solution deposits a coating of the metal on the article.

**Copper-plating.**—As an experiment, let it be supposed that it is desired to copper-plate a small object. Make up a solution of copper sulphate in the proportion of 1 lb. of sulphate to half a gallon of water. Add 4 oz. of sulphuric acid to the solution and suspend the object from the negative rod. A small plate of copper must then be suspended from the other rod and a 4-volt battery connected.

The passage of the current through the solution breaks up the copper sulphate into pure copper and sulphuric acid and deposits the copper on the object, which, within a few minutes, becomes coated with a “blush” of copper. The coating of copper becomes thicker and thicker as long as the current is permitted to flow.

The sulphuric acid which is formed by the decomposition of the copper sulphate attacks the copper plate and combines with it to form fresh copper sulphate. In this manner the composition of the solution remains unaltered throughout the process, but, of course, the copper plate is gradually eaten away.

It is not in the least necessary that the copper plate, or “anode” as it is termed, should be pure copper, because any impurities will be precipitated to the bottom of the solution as sludge, only pure copper being deposited on the spoon.

In order to deposit nickel on the object, we should require to use a nickel solution and a nickel anode; to deposit silver we should use a silver salt and a silver anode; and so on.

**Cleaning Process.**—It is very important that the object to be plated should be thoroughly cleaned before the plating process, as otherwise the plating will not be durable, and will not adhere firmly. Cleanliness in the ordinary domestic sense is not sufficient—the article must be, absolutely and chemically clean.

Some idea of the care required in cleaning may be gained from the fact that if the article is touched by hand before plating,

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the coating will not adhere to those parts which have been touched.

Commercial electro-plating is a more complicated process than the simple one outlined above, although the principle is identical. The process is complicated by the number of cleaning and washing baths through which the article must pass if the plating is to be sound and a satisfactory job. First of all, the article must be mechanically cleaned, either by emery or by sand-blasting. It is then cleaned by immersion in various acid or alkaline solutions, according to the particular metal.

If the article is required to have a highly polished surface after plating, it must be highly polished before any attempt is made to plate it, because it is most difficult to get a really good finish if the plating is done on an unpolished base, and if the polishing is left until afterwards. Commercially the polishing is accomplished by holding the article against a rapidly revolving buff (see **Polishing**), made of many thicknesses of cotton cloth. The buffs receive frequent applications of polishing compositions, which generally consist of a thick grease mixed with Tripoli, emery, or rouge, according to the nature of the metals and the degree of polish required.

**Removing Grease.**—In order to remove any grease on the surface the article passes through a hot potash bath which is worked at about 200° F. This bath converts any animal or vegetable fats which may be on the surface into soap, which rises to the surface. After being washed in cold water, the article is ready for the next bath, the constitution of which depends on the plating process to be used.

Nickel-plating is probably the most important commercial process, and to illustrate the general practice of commercial electro-plating the nickel process will be described in detail.

Where the quantity of plating to be carried out is small, the articles are usually transferred from one bath to the other by hand, but where a very large number of similar objects require to be plated, as is usually the case in a commercial works, then large automatic machines are used to facilitate mass production. The automatic plant has the advantage that all operations are correctly carried out, with consequent uniformity in the thickness of the deposit and improved quality of plating.

The various vats are generally placed in line, one behind the other in their proper sequence. Conveyor chains are arranged to move slowly along the line of vats, the articles to be plated being suspended from cross-rods.

The suspended articles pass successively through all the preparatory cleaning and swilling vats before entering the plating vat, and they are then finally washed after plating.

At the end of each vat the articles are lifted automatically

## ELECTRO-PLATING

by an auxiliary chain, carried forward, and deposited again in the next vat. The various vats are designed to allow the articles to remain in a particular vat for a predetermined time, which cannot be altered without altering the plant.

**Various Plating Solutions.**—A commercial nickel-plating plant comprises the following processes :

*Vat No. 1*—Degreasing. After the articles have been mechanically cleaned and polished, they are chemically cleaned, in a hot, alkaline solution, of all grease.

*Vat No. 2*—Cold-water swill.

*Vat No. 3*—Cyanide dip. They then pass through a cyanide bath consisting of 8 oz. of potassium cyanide to 1 gallon of water, to remove any stains caused by the potash solutions and to give a final clean.

*Vat No. 4*—Another wash in cold water.

*Vat No. 5*—Acid dip. They then enter an acid bath, usually consisting of dilute sulphuric acid, to remove all traces of cleaning solutions and to leave the articles absolutely clean and bright.

*Vat No. 6*—A further wash in cold water.

*Vat No. 7*—Electro-plating. In the case of nickel-plating, this bath consists of a hot solution of nickel sulphate, nickel chloride, boric acid, and water. The solution is kept agitated by means of compressed air, and the articles remain in the bath until they have acquired the correct thickness of deposit.

*Vat No. 8*—Wash in cold water.

*Vat No. 9*—Wash in hot water.

The articles are then dried and repolished according to the finish required.

While the usual object of electro-plating is to protect the base metal from corrosion, and to increase the decorative appearance, these are by no means the only uses.

One very important process is for the "building up" of under-size or worn metal parts. In engineering work it sometimes happens that some expensive machined part may become worn through continual use. Until recent years, such a part would have had to be scrapped, but to-day it may be built up to the correct size by properly controlled nickel-plating methods. More frequently it is built up oversize, and then machined down to the correct size. In ordinary electro-plating the thickness of the plating is only about 0.001 in., but in this special repair work the thickness may be as much as a quarter of an inch.

**Chromium-plating.**—Chromium owes its remarkable stainless qualities to the formation of an extremely thin, invisible film of oxide over the surface, as the result of which the metal loses its chemical activity. It becomes non-reactive, and in this condition it resists to a remarkable degree the corroding agencies which would otherwise rapidly result in tarnish. Chromium is

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an intensely hard metal ; in fact, it may be deposited in such a hard state that it will easily cut glass. Its wear-resisting qualities are consequently excellent.

Unfortunately, chromium cannot be deposited directly upon any of the common base metals, as it forms a powerful electric coupling in the presence of any moisture which results in the oxidisation of the underlying metals. The chromium layer is then forced off in the form of tiny flakes. The electrical action between nickel and chromium, however, is very much less than between chromium and any other common metal, and consequently a thick layer of nickel is invariably deposited before the chromium. The nickel is a protection for the base metal, while the chromium protects the nickel and prevents oxidisation or tarnishing.

It must be mentioned that poisonous fumes are evolved during the process, and the work should, therefore, be done out of doors.

The following formulæ give the solutions most frequently used in the actual plating bath :

1. Copper-plating :

Copper sulphate	.	.	.	.	.	2 lb.
Sulphuric acid	.	.	.	.	.	8 oz.
Water	.	.	.	.	.	1 gallon

2. Nickel-plating :

Nickel sulphate	.	.	.	.	.	2 lb.
Nickel chloride	.	.	.	.	.	2 oz.
Boric acid	.	.	.	.	.	4 oz.
Water	.	.	.	.	.	1 gallon

3. Chromium-plating :

Chromic acid	.	.	.	.	.	2½ lb.
Sulphuric acid	.	.	.	.	.	½ oz.
Water	.	.	.	.	.	1 gallon

4. Silver-plating :

Silver cyanide	.	.	.	.	.	5 oz.
Sodium cyanide	.	.	.	.	.	5½ oz.
Water	.	.	.	.	.	1 gallon

**Rhodium-plating.**—Rhodium as a plating metal is of very recent date, yet, owing to the excellent results obtained by the process, rhodium-plating has achieved a well-deserved popularity for decorative purposes.

Rhodium is a member of the platinum group of metals. It is, of course, a rare and expensive metal, but, fortunately, only a small quantity of rhodium salt is required for plating purposes, and, after the rhodium-plating bath has once been set up, its actual running costs are very low.

An effective rhodium-plating bath may be made up according to the following formula :

#### ELECTRO-PLATING

Rhodium sulphate . . . . .	0.25 gram
Ammonium sulphate (pure) . . . . .	8.0 ,,"
Sulphuric acid (conc.) . . . . .	16.0 ,,"
Water . . . . .	250.0 c.c.

This bath should be used at a temperature of 50° C. The anode should comprise a carbon rod, or, better still, a thin strip of platinum, whilst the cathode consists of the silver or silver-plated article which is to be plated.

A small battery of 2 volts should be used with the bath, the "current density" (i.e. the measurement of the current passing through a given area of cathode surface) being about 60-70 amps. per square foot of surface to be plated. Thus it will be seen that a fairly heavy current at low voltage is required.

The current should be passed for from 20 to 30 seconds. This will give a very close-grained deposit of metallic rhodium on the silver article, after which the latter should be withdrawn from the bath, carefully drained, well washed, and finally dried and subjected to a light polishing. The rhodium-containing electrolyte must be contained in a porcelain, glass, or enamelled vessel and not in a metallic one.

## POLISHING AND FINISHING METAL

No mechanic can afford to ignore the art of finishing metalwork, and this section explains every detail of the processes involved. Many engineers' workshops can be greatly improved by the addition of a few polishing and emery wheels, provided, of course, that there is power available to drive them. Once the "kit" is purchased (cloth wheels, emery wheels, soaps, etc.), there is practically no further expense, as the materials are very lasting, even with hard usage. Every kind of polishing job which is finished off with polishing mops is very much more satisfactory than the job which is simply wiped over with a rag. In this section it is intended to give full details of the art of polishing, and to give solutions to many problems which the novice may meet.

**Power Necessary.**—The first obstacle which crops up is the question of power. Quite frankly, if there is a lot of heavy buffing to be done, at least a 1-h.p. motor is required with a speed of 2,000 to 3,000 revolutions per minute. A squirrel-cage motor is most suitable for the purpose as regards economy and stability. Such a motor will answer the purpose for every phase of first-class polishing. On the other hand, a light polishing machine can be driven by a  $\frac{1}{6}$ -h.p. motor, which will be found quite satisfactory, enabling all metals of fairly good surface to be brought up to a very nice finish.

In large factories the polishing shop is particularly interesting. There may be anything up to thirty wheels of different kinds and speeds, being driven from overhead pulleys. An enormous amount of dust is created by the wearing away of wheels, but the water helps to counteract this. The real idea of the water, however, is to act as a sort of lubricant, enabling the work to be turned out to a fine degree of finish; the water is kept trickling down on the rapidly revolving wheels.

**Preparing Castings.**—When castings come out of the moulds they are first ground on coarse emery wheels, where all the bumps and hollows are removed, then passed on to finer wheels, until eventually they are cloth-polished with a super-finish soap, and a very high-speed wheel.

Regarding the different wheels which are used: the emery wheel is simply made of wood or felt with a sheet of emery cloth glued round; it is a constant source of trouble, inasmuch as it is extremely difficult to get it to run on its spindle perfectly true. The central hole in the wheel is usually too large for the spindle, and to overcome this the wheel is often clamped up tight. If much pressure is put on such a wheel it will shift,

## POLISHING AND FINISHING METAL

and if it does, it will play havoc. Even when they are only slightly out of true they make considerable noise when in use.

**Mounting Emery Wheels.**—A good remedy for this is as follows: turn a piece of steel the exact diameter of the spindle on which the wheel is to be mounted, and place it into a piece of wood. Then place the emery wheel on the wood. Care must be taken to get the spindle set square in relation to the wood. Place the wheel as central as possible, and measure carefully from the outside edge of wheel to the opposite side of shaft, continuing all the way round. The distance at which to set the callipers is easily calculated from the diameter of the wheel and the spindle. When all is carefully adjusted, pour in molten lead, filling up the space between the spindle and the hole in the wheel. This method will be found to give excellent results. When clamping up the wheel a couple of cardboard discs inserted between the clamping washers and the wheel will increase the driving friction without tightening up too much with the risk of cracking the wheel.

Having fixed up the emery "bob," a few words concerning its use will be helpful. When using a bob it is important that a plentiful supply of grease or oil be used as a lubricant, otherwise the casting will turn out a burnt colour which cannot be removed; this, of course, is owing to the excessive friction caused when grinding. When the metal to be polished contains scratches, they should always be removed in this manner.

**Cloth Wheels.** Next comes the cloth wheels. These are made chiefly of linen sheets piled together. On some wheels these sheets are stitched together and are called stitch mops; they are used for "roughing"; owing to centrifugal force, these wheels are quite hard when running. Another serviceable "mop" is the scratch mop, and is made of wire bristles—a most excellent tool for scratching off old rust, etc. The lubricant used on the cloth consists chiefly of bath-brick and rotten-stone, and a super-finish soap which is made of lime. The lubricant should be constantly rubbed on the wheel, and the latter should never run dry or shiny, otherwise it will not polish efficiently. To remove scratches, keep applying a fair quantity of soap, and let the wheel rub on the one spot for a while. When all the scratches are removed it is time for a final finish. This should be done on another wheel, using the lime soap. The operator should work systematically, that is, start at the bottom and work in a horizontal motion, upwards; when done in this manner the job will have no "wheel marks" in it. The work in hand, especially on a high-speed motor, should always be gripped firmly, and on no account should a sharp edge be allowed near the wheel, or else it will tear the job from the operator's hands. These remarks are most important, and an amateur will soon see for

himself that there is quite an art in getting a perfectly glassy surface. If, however, the job is carried out as above, a really excellent finish can be obtained. Any dirty soap marks which still remain on the work can be easily rubbed off with a drop of petrol.

**Brushing Wheels.**—Another class of wheel is the “brushing” type, under which class come brass-wire, steel-wire, and nickel-silver-wire wheels.

The brass-wire fine wheel is used for putting a fine dead surface on coloured gold work, for finishing sand-blasted gold and silver, and for producing a very dead finish on silver work. The medium brass-wire wheel is used for coarse frosting and scratching before the plating, and also for bronzing, brassing, coppering, etc. ; while the coarse-type wheel is for scratching before burnishing, and for cast brass, copper, and iron articles after pickling.

The steel-wire fine wheel is used for all work requiring a coarse dead frost, and for bronzed jewellery, bronzed brass, and copper work. The fine type is for frosting aluminium and general scratch brushing, while the coarse type is for heavy work, castings, etc.

Finally, the nickel-silver-wire wheel is used for retaining a white finish on silver and nickel, and also on aluminium articles prior to chrome plating.

**Spindle Speeds.**—The speed at which brushing wheels are revolved is an important matter. It should be remembered that wire wheels must always run more slowly than bristle or fibre wheels ; also that the larger the wheel and the coarser the wire, the more slowly it must revolve. The following speeds are recommended for average working conditions :

Small bristle and fibre wheels . . . . .	2,500 r.p.m.
Large bristle and fibre wheels . . . . .	2,000 “
Fine-wire scratch wheels . . . . .	1,600–1,700 “
Medium-wire scratch wheels . . . . .	1,200–1,500 “
Coarse-wire scratch wheels . . . . .	700–1,000 “
Extra heavy wire scratch wheels . . . . .	500–600 “

To prevent wire brushes and wheels rusting when not in use, lay them in a basin of water in which a little lime has been added.

If the dust created by the wearing of these wheels becomes a serious question, a guard can be made.

The guard is made from sheet steel, bent to shape, and riveted. The baffle plate should be set at such an angle as to prevent the air from rushing through the slot for the wheel.

**A Polish for Brass and Copper.**—Take  $\frac{1}{2}$  lb. of rotten-stone,  $1\frac{1}{2}$  oz. of oxalic acid, and  $\frac{1}{2}$  oz. of gum arabic. Finely powder these ingredients, then make a paste by stirring into the dry ingredients  $1\frac{1}{2}$  oz. of sweet oil and as much water as necessary.

## CHEMICAL COLOURING OF METALS

THE art of metal colouring is as old as the proverbial hills. The ancient Egyptians coloured many of their metals by chemical processes, some of which are well recognised, others of which are nowadays unknown. Indeed, if a metal is left alone for a sufficient length of time, it invariably tends to colour itself. Thus copper, for instance, will either turn green or brown according to the conditions under which it has been exposed. Zinc and lead will usually acquire a whitish appearance; iron, of course, will turn brick-red in hue; whilst even gold itself will, in some conditions, acquire a deeper and mellower colouration.

The colouring of metals by chemical means is usually termed "bronzing," although strictly speaking, such a term should only be applied to the browning of metals. If, however, we turn iron blue or copper green, we usually refer to the "bronzing" of the metal.

Not infrequently, the home mechanic, after completing a piece of metalwork, feels the desire to "bronze" or colour his metal object some definite hue and shade. Usually, in the case of the common metals and alloys, this object is not difficult to fulfil.

**Polishing and Cleaning.**—It is of the greatest importance that all metal objects selected for chemical colouring be perfectly clean. The object should first be polished. Then it should be "degreased" by swabbing it over with methylated spirit or some other grease solvent. Finally, it may be advisable to dip the metal object in a bath of warm dilute hydrochloric acid (spirits of salts) for a minute or two in order to scour it thoroughly. After this treatment, the object is rinsed in warm water, and is then ready for "bronzing."

If a metal object is not scrupulously clean, its subsequent colouring will very frequently be patchy and uneven. Also, the colouring may not be permanent. Hence, it will be clear that a thorough cleaning of the metal object before "bronzing" or colouring is an essential to the success of whatever process may be used, and in all the instructions for chemical colouring given in this section, it will be assumed that the metal object undergoing the process has previously been thoroughly cleaned and, indeed, scoured.

**A Dead-black Surface.**—Most common metals can be given a dead-black surface colouration very readily by chemical means. For instrument work, such a colouration is very useful and often, indeed, a necessity. The black colour, unlike many of the

## . DICTIONARY OF METALS AND ALLOYS

Painted-on lacquers, does not flake off or chip away. Brass and copper articles can be blackened by immersion for a few minutes in the following liquid :

Copper nitrate . . . . .	1 oz.
Water . . . . .	3 oz.

A small quantity of silver nitrate dissolved in the above solution is said to improve the black colouration produced upon the metal, but its employment is by no means essential.

Copper (but not brass) articles may be made to acquire a slightly shiny black surface by immersion in the following solution :

Ammonium sulphite (Liver of sulphur) . . .	1 part
Water . . . . .	4 parts

Brass articles take upon themselves a steely-grey colour in this solution.

By immersing iron articles in a solution of photographers' "hypo," they are given a blue-black colour, particularly if a little lead acetate or nitrate is dissolved in the hypo. Silver immersed in sodium-sulphide solution turns almost black, while a black colour on zinc can be obtained by immersing it in a solution of antimony chloride.

A pleasant grey colour is produced on iron by boiling it for half an hour in a weak solution of iron phosphate. This process is akin to that of "coslettisation," a thin film of iron phosphate and oxide being formed on the surface of the metal.

In order to colour brass or copper a variety of shades ending in black, the metals should be immersed in a very dilute solution of ammonium or sodium sulphide. Brass, for instance, placed in an extremely dilute solution of either of these sulphides will acquire a golden appearance, whilst copper, in the same solution, will be reddened. By making these sulphide colouring solutions stronger or by allowing a longer time for them to act upon the metal, the mechanic will find that he can get almost any yellow, red, brown or black colour he desires on these metals.

Steel articles can be "blued" simply by passing them through a flame. Better still, they may be blued by boiling them for a short time in a strong solution of hypo containing a little lead nitrate.

**Antique Effects.**—The production of antique effects on articles of brass and copper will be of interest to many readers, since by careful working, beautiful effects of these metals can be obtained fairly readily. The green or brown colouration which an article of brass or copper usually acquires by age and from exposure to the elements is termed a "patina," the word signifying an encrustation. Copper, bronze, and brass patinas can be divided

## CHEMICAL COLOURING OF METALS

into two varieties, namely green and brown. The latter is the easier to imitate by chemical means. If, for instance, an article of copper is dipped in a dilute solution of sodium sulphide, it will instantly acquire a brown patina, the exact shade and depth of the colouration being dependent upon the strength of the sulphide solution. Brass acquires a good patina of the brownish variety when it is heated in a paste made of sulphur and lime.

The green patina which is often seen on brass or copper articles of great age, and which is often very beautiful in appearance, consists, for the most part, of a layer of copper carbonate. We may obtain such a patina on brass and copper articles by burying them in damp earth for a considerable period. Such a process, however, is a slow and an uncertain one.

**Green Patina.**—An excellent green patina can be given to copper and brass objects by suspending them from some improvised wooden stand and then placing them in an airtight container. With the container is placed also a small vessel containing some ordinary washing soda or bicarbonate of soda, together with a little water. The metal articles are brushed over with strong vinegar, or, better still, with dilute acetic acid, and a little of the acid is poured into the soda-containing vessel, the container then being immediately closed up. The carbon-dioxide gas evolved from the soda-acid mixture will react with the acetic acid on the metal articles, and gradually the latter will acquire a yellow-green colouration and a hard shiny surface.

The operations mentioned in the above paragraph should be repeated every alternate day until the metal articles have been sufficiently coloured, a task which will occupy about two or three weeks.

A quicker method of obtaining a green colour upon brass or copper articles consists in painting them over daily with the following solution :

Copper carbonate	.	.	.	.	.	3 parts
Sal-ammoniac	.	.	.	.	.	1 part
Common salt	.	.	.	.	.	1 "
Copper acetate	.	.	.	.	.	1 "
Cream of tartar	.	.	.	.	.	1 "
Strong vinegar	.	.	.	.	.	8 parts

This solution gives a blue-green colouration which takes about four complete days to develop.

Quite a good yellow-green colouration may be obtained on copper and brass (particularly the latter) articles by brushing them over daily with a mixture of vinegar, common salt, and ordinary sugar.

Note that for the production of these antique green colourations the metals must not be immersed in the solutions, but merely brushed over with them.

**Dulled Aluminium.**—The silvery appearance of aluminium is not always desirable. It may, however, be permanently and uniformly dulled by dipping the metal in a hot, moderately strong solution of caustic soda (sodium hydroxide) for a few seconds. The metal will thereafter have a matt appearance. If aluminium so treated is immediately rinsed in warm water and then immersed in a hot solution of an aniline dye, the aluminium surface will take up a little of the dyestuff, and will become permanently tinted. This constitutes an imitation of the now well-known process of "anodising" aluminium and the subsequent "dyeing" of the metal.

By immersing zinc in a hot solution of ammonium molybdate containing a little free ammonia, a deposit of metallic molybdenum will be obtained on the surface of the zinc. This "molybdenum-plated" zinc has a very fine colour, ranging from an iridescent golden yellow to a steely brown. Aluminium articles can be made to acquire a dusky hue by the same process.

What is known as "oxidised silver" is simply silver which has been immersed in a weak solution of liver of sulphur (potassium sulphide) containing a little ammonia. Very weak solutions produce the best results, for in strong solutions the silver is merely blackened.

Similarly, nickel-plated articles may be "oxidised" by immersion for a few seconds in the above solution, in which they usually acquire a dark golden tint.

Brass articles may be made to acquire an extraordinary series of colourations ranging from pale gold to pink and pale blue simply by immersing them in a solution containing half an ounce each of lead acetate and "hypo" (sodium hyposulphite) to the pint of water.

**Permanent Colouration.**—It is difficult to get good permanent colourations on tin objects. If, however, a sheet of tin is heated to near its melting-point and is then suddenly plunged into the following solution, nitric acid, 1 part, sulphuric acid, 10 parts, water, 89 parts, the surface of the metal will acquire a very beautiful crystalline appearance to which the term *moiré métallique* (watered metal) has been applied.

## Table of Elements

(Arranged according to Mendeléef's Periodic Law)

Atomic Number	Element	Atomic Weight
First Period :		
1	Hydrogen . . . . .	1.008
2	Helium . . . . .	4.00
Second Period :		
3	Lithium . . . . .	6.94
4	Beryllium . . . . .	9.01
5	Boron . . . . .	10.82
6	Carbon . . . . .	12.00
7	Nitrogen . . . . .	14.01
8	Oxygen . . . . .	16.00
9	Fluorine . . . . .	19.00
10	Neon . . . . .	20.2
Third Period :		
11	Sodium . . . . .	23.00
12	Magnesium . . . . .	24.32
13	Aluminium . . . . .	27.1
14	Silicon . . . . .	28.3
15	Phosphorus . . . . .	31.04
16	Sulphur . . . . .	32.06
17	Chlorine . . . . .	35.46
18	Argon . . . . .	39.88
Fourth Period :		
19	Potassium . . . . .	39.10
20	Calcium . . . . .	40.07
21	Scandium . . . . .	44.1
22	Titanium . . . . .	48.1
23	Vanadium . . . . .	51.0
24	Chromium . . . . .	52.0
25	Manganese . . . . .	54.93
26	Iron . . . . .	55.84
27	Cobalt . . . . .	58.97
28	Nickel . . . . .	58.68
29	Copper . . . . .	63.57

## DICTIONARY OF METALS AND ALLOYS

Table of Elements—*continued*

Atomic Number	Element	Atomic Weight.
30	Zinc	65.37
31	Gallium	69.9
32	Germanium	72.5
33	Arsenic	74.96
34	Selenium	79.2
35	Bromine	79.92
36	Krypton	82.92
Fifth Period:		
37	Rubidium	85.45
38	Strontium	87.63
39	Yttrium	88.7
40	Zirconium	90.6
41	Niobium	93.5
42	Molybdenum	96.0
43	Masurium	—
44	Ruthenium	101.7
45	Rhodium	102.9
46	Palladium	106.7
47	Silver	107.88
48	Cadmium	112.40
49	Indium	114.8
50	Tin	118.7
51	Antimony	120.2
52	Tellurium	127.5
53	Iodine	126.92
54	Xenon	130.2
Sixth Period:		
55	Cæsium	132.81
56	Barium	137.37
Rare Earths	Lanthanum	139.0
	Cærium	140.25
	Praseodymium	140.9
	Neodymium	144.3
	Illinium	—

TABLE OF ELEMENTS

Table of Elements—*continued*

Atomic Number	Element	Atomic Weight
62	Samarium . . . . .	150.4
63	Europium . . . . .	152.0
64	Cadolinium . . . . .	157.3
65	Terbium . . . . .	159.2
66	Dysprosium . . . . .	162.5
67	Holmium . . . . .	163.5
68	Erbium . . . . .	167.7
69	Thulium . . . . .	168.5
70	YTTerbium . . . . .	173.5
71	Lutecium . . . . .	175.0
72	Hafnium . . . . .	178.0
73	Tantalum . . . . .	181.5
74	Tungsten . . . . .	184.0
75	Rhenium . . . . .	186
76	Osmium . . . . .	190.9
77	Iridium . . . . .	193.1
78	Platinum . . . . .	195.2
79	Gold . . . . .	197.2
80	Mercury . . . . .	200.6
81	Thallium . . . . .	204.4
82	Lead . . . . .	207.2
83	Bismuth . . . . .	209.0
84	Polonium . . . . .	210.0
85		
86	Niton . . . . .	222.0
Seventh Period :		
87		
88	Radium . . . . .	226.0
89	Actinium . . . . .	227.0
90	Thorium . . . . .	232.12
91	Protoactinium . . . . .	236.0
92	Uranium . . . . .	238.2

# A Table of Principal Elements arranged in Order of Valency

	Name	Symbol	Atomic Weight
MONOVALENT	Bromine . . . . .	Br	79.92
	Chlorine . . . . .	Cl	35.5
	Fluorine . . . . .	Fl	19
	Hydrogen . . . . .	H	1.008
	Iodine . . . . .	I	126.92
	Potassium . . . . .	K	39.1
	Silver . . . . .	Ag	107.88
	Sodium . . . . .	Na	23
DIVALENT	Barium . . . . .	Ba	137.37
	Cadmium . . . . .	Cd	112.40
	Calcium . . . . .	Ca	40.07
	Copper . . . . .	Cu	63.57
	Magnesium . . . . .	Mg	24.32
	Mercury . . . . .	Hg	200.6
	Oxygen . . . . .	O	16
	Zinc . . . . .	Zn	65.37
TRIVALENT	Aluminium . . . . .	Al	27.1
	Bismuth . . . . .	Bi	208
	Boron . . . . .	B	11
	Cobalt . . . . .	Co	58.97
	Gold . . . . .	Au	197.2
	Iron . . . . .	Fe	55.84
TETRAVALENT	Nickel . . . . .	Ni	58.68
	Carbon . . . . .	C	12.005
	Lead . . . . .	Pb	207.2
	Platinum . . . . .	Pt	195.2
	Silicon . . . . .	Si	28.3
	Tin . . . . .	Sn	118.7
PENTAVALENT	Antimony . . . . .	Sb	120.2
	Arsenic . . . . .	As	74.96
	Nitrogen . . . . .	N	14.01
	Phosphorus . . . . .	P	31.04
HEXAVALENT	Chromium . . . . .	Cr	52
	Manganese . . . . .	Mn	54.93
	Sulphur . . . . .	S	32.06

## THE HARDNESS TEST

THERE are many systems of testing the hardness of metals. Four of the chief are the sclerometer which was produced by Turner in 1886, the indentation test adopted by Brinell in 1900, the scleroscope devised by Shore, and Keep's drill test. In the sclerometer test a diamond is subjected to a known pressure upon the material to be tested. It pricks the surface of the metal and the dial attached gives a reading of the depth of the penetration. In another test, a diamond with known weight attached is drawn backward and forward over the surface to be tested. A hardness number is ascribed according to a comparison of the scratch with a standard scratch. The hardness number is really the weight in grams which will produce a standard scratch. In the scleroscope a hardened point is attached to a small cylinder of steel and it is allowed to fall upon the surface of the metal. In this case, it is the height of the rebound which is taken as the measure of hardness. The weight of the hammer is about 40 grains, whilst the height of the rebound is about 100 on the scale—equivalent to  $6\frac{1}{2}$  ins. whilst the maximum fall is 254 millimetres or about 10 ins.

Keep's test makes use of an apparatus in which a standard steel drill is caused to revolve a definite number of times whilst pressed with a standard pressure against the specimen under test. The hardness is graphically recorded on a sheet. A dead soft material would give a horizontal line, whilst a material of a hardness equivalent to the drill itself would give a vertical line. Intermediate degrees of hardness will obviously be between the horizontal and the vertical.

One of the best known tests is the Brinell, in which a hardened steel ball is pressed into the surface of the metal, and makes an indentation the diameter of which is measured under the microscope. The area of the indentation is calculated and as the indentation is made under a known pressure, it is possible to calculate the stress per unit of area when the ball comes to rest. From this the hardness number is derived. The pressure in kilograms for making the impression is divided by the area of the impression expressed in square millimetres. The answer is known as the hardness numeral. The standard diameter of the ball is 10 millimetres, and the standard pressure 6,614 lb. or 3,000 kilograms for steel and iron, but in the case of some of the softer metals a pressure of 500 kilograms or 1,102 lb. is used. A table of Brinell hardness numbers is given on next page.

# BRINELL HARDNESS NUMBERS

(For Load or Pressure of 3,000 kilograms)

Diam. of Im- pression mm.	Hard- ness Number						
2.0	946	3.25	351	4.5	179	5.75	105
2.05	898	3.3	340	4.55	174	5.8	103
2.1	857	3.35	332	4.6	170	5.85	101
2.15	817	3.4	321	4.65	166	5.9	99
2.2	782	3.45	311	4.7	163	5.95	97
2.25	744	3.5	302	4.75	159	6.0	95
2.3	713	3.55	293	4.8	156	6.05	94
2.35	683	3.6	286	4.85	153	6.1	92
2.4	652	3.65	277	4.9	149	6.15	90
2.45	627	3.7	269	4.95	146	6.2	89
2.5	600	3.75	262	5.0	143	6.25	87
2.55	578	3.8	255	5.05	140	6.3	86
2.6	555	3.85	248	5.1	137	6.35	84
2.65	532	3.9	241	5.15	134	6.4	82
2.7	512	3.95	235	5.2	131	6.45	81
2.75	495	4.0	228	5.25	128	6.5	80
2.8	477	4.05	223	5.3	126	6.55	79
2.85	460	4.1	217	5.35	124	6.6	77
2.9	444	4.15	212	5.4	121	6.65	76
2.95	430	4.2	207	5.45	118	6.7	74
3.0	418	4.25	202	5.5	116	6.75	73
3.05	402	4.3	196	5.55	114	6.8	71.5
3.1	387	4.35	192	5.6	112	6.85	70
3.15	375	4.4	187	5.65	109	6.9	69
3.2	364	4.45	183	5.7	107	6.95	68

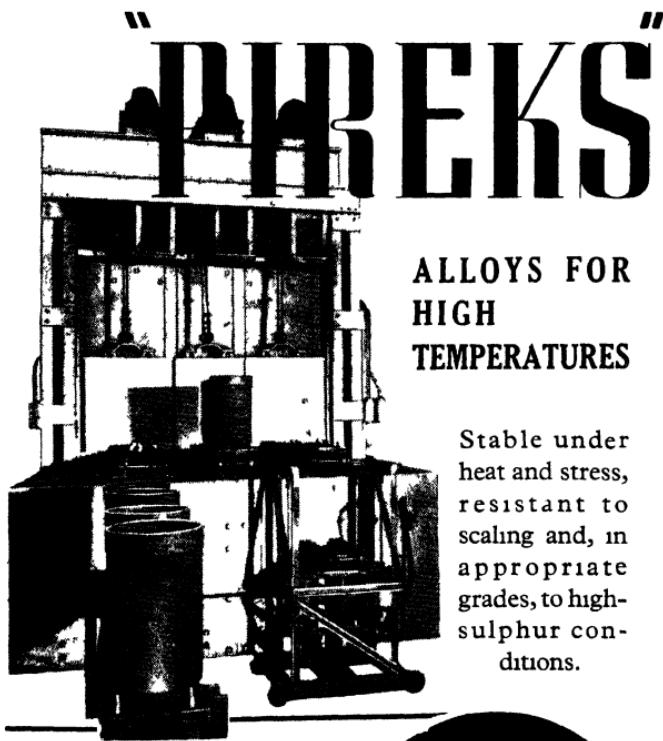
For other test loads or pressures the hardness numbers are proportional to those given in the table.

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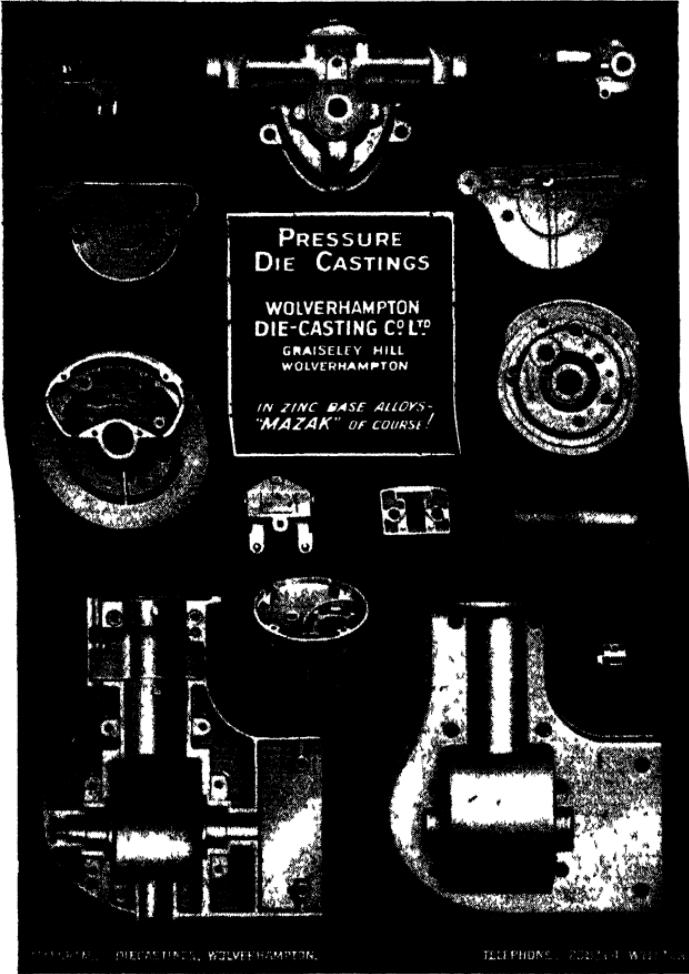
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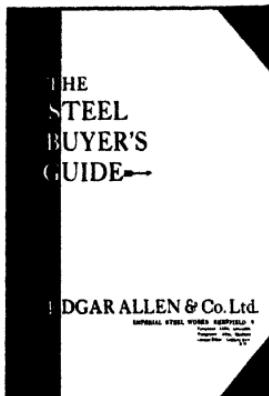
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